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PORTO RICO AGRICULTURAL EXPERIMENT STATION.**D. W. MAY, Special Agent in Charge.****ANNUAL REPORT****OF THE****PORTO RICO****AGRICULTURAL EXPERIMENT STATION****FOR 1906.**

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1907.

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PORTE RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

- D. W. MAY, *Special Agent in Charge and Animal Husbandman.*
- J. W. VAN LEENHOFF, *Coffee Expert.*
- W. V. TOWER, *Entomologist and Plant Pathologist.*
- M. J. IORNS, *Horticulturist.*
- E. F. CURT, *Farm Superintendent.*

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LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., February 15, 1907.

SIR: I have the honor to transmit herewith and recommend for publication the Annual Report of the Porto Rico Agricultural Experiment Station for the fiscal year 1906.

Respectfully,

D. W. MAY,

Special Agent in Charge.

Dr. A. C. TRUE,

Director Office of Experiment Stations.

U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON,

Secretary of Agriculture.

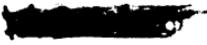
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ANNUAL REPORT OF THE PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1906.^a



SUMMARY OF INVESTIGATIONS.

By D. W. MAY, *Special Agent in Charge.*

INTRODUCTION.

The progress of agriculture in Porto Rico, with which the experiment station has been connected, has been decidedly marked during the year. This has been due to various causes. First should be mentioned the improvement in agricultural practice made by the native planters of Porto Rico. They are studying their soils, their crops, and the scientific progress of their business as exemplified by the work of the experiment stations. A decided increase in the interest of the work of their own station can be noticed, and a growing desire for the reports and a personal interest in the work itself. It is impossible for the station to reach all classes of the native inhabitants, but in every community there are found progressive planters who are taking up improved agriculture and are also imparting instruction to their neighbors. It is very encouraging to see intelligent planters who read and study facts imparting information to the small farmers and peons of their localities. Another factor that is having a great influence in the agricultural development of the island is the influx of planters from the United States, who are going in especially for fruit growing. These men come to the island for the purpose of making it their home, and their operations redound to the permanent prosperity of the island by reason of the fact that they improve their lands and greatly increase their productive capacity, and at the same time the profits arising from their efforts are reinvested here. A third factor, and a large one, that is working for the quick development of Porto Rico is the larger corporations that are locating here for the development of tropical industries. The first of these were interested in the production of sugar; their operations are evident in the great change that has come over this

^aThis is the sixth annual report of this station. Previous reports will be found in Annual Reports of the Office of Experiment Stations, 1901, pp. 381-415; 1902, pp. 331-357; 1903, pp. 419-468; 1904, pp. 383-424; and Office of Experiment Stations Bulletin 171. A preliminary report on the agricultural resources and capabilities of Porto Rico was published as House Document 171, Fifty-sixth Congress, second session.

production since the American occupation. The central factory system has supplanted the small mills with their open kettles and low extraction. These large "centrals" consume the cane grown in distances of 40 to 50 miles, and their operation has resulted in the abandonment of many small mills that now stand idle in the fields. The large centrals purchase the greater amount of their cane from the planters, or else manufacture the sugar on a percentage basis. The small growers find it more profitable to dispose of their cane in this way than to grind it in their small mills of low capacity. In addition to grinding cane of others, the large centrals are growing more or less cane, for the larger part on leased land. Such plantings are usually carried out under the best conditions, taking advantage of the more modern aids of science. This has a good effect upon the various communities in which such plantings are made by reason of the fact that many planters in the neighborhood watch the results and take advantage of the improved methods demonstrated.

The one crop that has made the greatest advances during the year under consideration is tobacco. There has been a decided improvement in the quality as well as the quantity of this product. The improvement of the quality of the Porto Rican leaf has called the attention of capitalists to the possibilities of this crop in the island. Corporations backed by capital have come in for the purpose of not only growing tobaccos, but of manufacturing them, taking advantage of the plentiful supply of cheap labor abounding here. Many acres, especially in the valleys of the interior, have been put under cultivation and prices of lands adapted to tobacco growing have increased enormously. Large factories have been erected in San Juan, Bayamon, and Caguas, employing hundreds of people. These large companies are not only planting tobaccos, but are buying much more from the small cultivators. A growing practice is for the handlers to buy the crop in the field from the smaller growers, curing and fermenting the plants themselves under the best scientific methods.

The coffee industry, which is the support of the larger number of the inhabitants of the island, has shown some improvement, brought about by the reestablishment of the plantations destroyed by the hurricane of 1899, together with a favorable crop year. A small amount of foreign capital has been invested in coffee plantations, but such investments are not as a rule being sought. Many of the plantations are heavily mortgaged, and such changes as are taking place in the holdings of such properties as a rule result from the foreclosures of these deeds of trust.

The plantings of fruits have been very rapidly extended, especially with citrus fruits and pineapples. These plantings are made almost altogether with foreign capital, and by people from the States, especially the Florida planters. From the results obtained in groves

of citrus fruits now coming into bearing, there is no doubt that very fine fruits of this class can be produced here. There is much yet to be learned in regard to methods of production, especially looking to the matter of decreasing the expense of bringing a grove into bearing. Shipping facilities also need to be much improved in order to put this fruit into the New York market with the minimum loss. Porto Rico has demonstrated the fact that it is peculiarly adapted to the production of the pineapple, and very fine luscious fruits can be grown here at a very low cost. Several million plants have been set during the year, mainly of imported slips of the Red Spanish variety from Cuba and Florida. The planting of the large native pine called Cabezona has also been greatly extended. While the larger part of this variety is canned, some successful shipments have been made to the New York market.

There has been a decided improvement with a number of other crops which will be noted under their separate heads. The work of the experiment station has been continued along the lines stated in the previous report. The demands have been great and in many cases urgent to expand the work, but the present income and resources will not justify the outlay necessary. The income for the station for the year has not increased materially, consisting, as in the previous year, of the Federal appropriation of \$15,000 and the receipts from the sale of products, the latter fund showing a small increase. Efforts were made to secure an additional appropriation from the insular legislature, but, owing to the limited resources of the island and heavy demands of the various local departments of the government, nothing was secured. While, in the writer's opinion, the experiment station is the source from which the improvement of the agricultural conditions will come, the economic situation of the island is such that certain other affairs are considered to be more urgent by the authorities. The anaemic disease prevailing among the inhabitants of the interior requires large appropriations at the present time to carry out the very efficient control remedies developed since the American occupation. Again, the illiteracy prevailing on the island has made demands very strongly in favor of educational work.

It is necessary that the income of this station be increased, and it is desirable that the Federal appropriation be augmented by extending the appropriations under the Adams Act, thereby putting the station on a basis similar to that of the stations in the States. The cost of operating a station in the Tropics is greater than in the Temperate Zone, freight rates are higher for all supplies, it is necessary to pay higher salaries in order to retain men in isolated places and under new and trying conditions, and the cost of cultivation of land is higher, owing to the continuous growing season and the rank spread

of vegetation. Again, the questions confronting the tropical stations are greater for several reasons than those in the Temperate Zone; there is more pioneer work to be done and there are many more problems to be worked out by reason of the fact that experimental work in the Tropics is comparatively new and stations are few and far between.

Mr. W. V. Tower has been added to the staff as entomologist and plant pathologist during the year. It is very desirable to add a chemist to the station and to fit up a chemical laboratory. This is a very urgent need if certain lines of work are continued and if other necessary experiments are undertaken. Owing to the establishment of other stations in Spanish-speaking countries and to the demand of large corporations in the Tropics for trained men as managers, the station should be in a position to pay better salaries and to hold men by being able to offer adequate inducements when they are solicited to go elsewhere.

FARM ENGINEERING.

The condition of the experiment station farm is being continually improved, as means will allow, by building roads, drains, irrigation ditches, and fences. The road running through the farm has been graveled, and another road is under construction into a valley where the operations of the station are now being extended.

The condition of the soils of the station has been greatly improved by tile drainage, and further drains are being laid from time to time as means will allow. Great interest has been taken by our planters in the drainage operations at the station, as we have the only tile mill in the island and are pioneers in this work. Heretofore surface drains have been constructed yearly at great expense. The station has sold tile to several planters for tiling their land and is encouraging this whenever possible. The municipality of Mayaguez allows the station to manufacture tile without paying the usual license fees, under agreement that this shall cease whenever private parties undertake their manufacture. Many acres of very valuable land can be reclaimed in the island by drainage, not only those soils that are too wet for profitable crops, but others in the drier sections that are alkaline. An area of soil on the experiment station farm that is now yielding the largest crops as a result of drainage has heretofore been worthless except for grass, because of the very large amounts of water it contained.

Experiments are being carried out in cement construction, especially in the making of fence posts. The station was fenced about three years ago, and already a great many of the posts have been replaced. Where there are so many wood-eating insects as in the Tropics, wood

construction should be supplanted by other materials where it is possible. The cement posts made by certain methods are proving very satisfactory. A post 4 by 4 inches at the base and 3 by 4 inches at the top can be made for 20 cents, and at this price proves far cheaper than wood posts.

A great many inquiries are made of the station regarding pumping and other machinery, and such questions are taken up as far as our time and ability will allow. In the drier sections of the island some very productive lands are being brought under cultivation by means of irrigation plants. Water is found from 20 to 80 feet below the surface and is raised by pumps of various descriptions. As this work is largely of a pioneer nature, it is very important that efforts of the planters be directed in the methods of bringing water to the surface and also in the improvement of the condition of the soils brought about by eliminating alkali.

LIVE STOCK.

There is great room for improvement in the various classes of live stock in Porto Rico. Very little pure-bred stock has been imported since the time of the early Spanish discoverers, and the result is that there has been very little improvement in the quality of the animals.

From the results reached at the experiment station and on the plantations, there seems no doubt that improved animals of the various breeds can be imported and successfully acclimated. There is also no doubt that the breeders can greatly improve their animals and obtain greater profits by the wise importation of new blood. Certain points, however, must be observed in acclimating animals from the Temperate Zone, or losses will occur.

The horse of Porto Rico is small but wiry. Some of them are very handsome and of great endurance, but in the States animals of the size common here would be classed as ponies. They are especially adapted for riding purposes and go the easy gaits very readily.

In importing horses into the island those breeds that are inclined to fleshiness should be avoided; a better type is the medium-sized lighter specimens of the standard bred or trotting horse and the American saddle-bred horse. Moreover, this type crosses better with the native animals, as they are nearer the same conformation. Even with these animals, however, in any extensive breeding operations monstrosities occur; that is, animals not well proportioned in their various parts.

While the importation of pure-bred animals from the States means a great deal for the improvement of the native stock, it should, at the same time, be borne in mind by our planters that great improvement

can also be reached by selecting their breeding animals with more care. This is a point that has been too greatly neglected in the past.

Many of the native cattle, considering the lack of care in breeding, are excellent individuals. The first requirement of the cattle of the island has been for work animals, and the beef and milk functions have been disregarded in any scheme of improvement. The animals, when they mature, which is rather late, make splendid work oxen on the cane plantations. To improve the race for beef or for milk production the shortest way is to import pure-bred bulls.

Imported animals should be kept in stables and fed cut grass, or, at least, should be kept in small lots well shaded until they become thoroughly acclimated. The second generation will probably be found as well acclimated as the native race, but animals brought from the States will not thrive if allowed to run in the hot sun and to have only the coarse grasses usually obtainable.

There is a difference of opinion as to whether tick fever exists in Porto Rico. From experiments made several years ago by the Bureau of Animal Industry of the United States Department of Agriculture, Washington,^a the conclusion was reached that this disease prevailed here. A veterinarian who has been on the island since the American occupation stated to the writer that it did not prevail. If it does it is not in a virulent form, or else our cattle are very immune to it. The station has had some 50 head of imported cattle from the States, all from north of the quarantine line. Of these three head were inoculated against tick fever; the others were not. While these animals were infested with ticks from the time of their arrival, there were no evidences of tick fever. Within ten days after arrival 200 ticks were taken from a 2-year-old Holstein cow, yet she showed no evidence of tick fever. However, all the animals at the station were well cared for and fed a plentiful supply of green grass at all times. Under such circumstances conditions are much more favorable than where animals are turned out in pastures without having special care. While the indications so far are that animals can be brought from the States and safely acclimated without being inoculated against tick fever, it is strongly advised that they be kept in places sheltered from the sun and be fed a plentiful supply of succulent grasses.

Pigs, turkeys, geese, ducks, and chickens have been acclimated without any serious losses at the station. The hatching of poultry, both under hens and in the incubators, has been carried on during the dry season and has been fairly successful. During the rainy season heavy losses of young chickens have been reported from several sections of the island. Breeders are advised to confine their hatching operations to the dry season for fowls and to properly protect them from the rains, and especially the damp grasses.

^a U. S. Dept. Agr., Bureau of Animal Industry Rpt. 1900, pp. 29, 426.

TOBACCO.

The station is not located in a tobacco-growing section. The soils are extremely heavy and the rainfall great. However, some experiments are being carried on, especially with the White Burley manufacturing tobacco grown in Kentucky. This tobacco grows very vigorously and produces very heavy yields. The crop brings locally about 12½ cents per pound, which is a very fair average for this variety. It is used by small local factories in making the low grade of cigars and also for manufacturing a chewing tobacco. Samples were submitted to several companies located in different sections of the island and seed were also sent them for trial. The manager of one of the largest companies stated that he thought it would make a good binder for cigars.

An extended scientific study of tobacco production in Porto Rico would be of great value at this time. Such work could be carried on at a minimum cost in cooperation with the companies now producing this crop. The services of a scientifically trained expert are necessary and he should devote his entire time to the work. The results reported in Bulletin 5 of this station on tobacco growing in the island have been very favorably received by our planters and the bulletin has been in great demand. Upon this as a basis further work needs to be carried out not only in the growing of tobacco but especially in the curing and fermentation of the product.

COFFEE.

A detailed account of the experiments with coffee during the year will be found in the report of the expert in charge of this work (p. 29). This has been a continuation of the methods of culture, the fertilization of the trees, and the introduction of foreign coffees. The coffees of Porto Rico have never been fertilized and more attention has been paid to this matter in our experimental work. The coffee tree lends itself readily to improvement by fertilizing the soils, and this crop in the island has decreased more in quantity than it has deteriorated in quality, so that the first real improvement in this product depends upon properly fertilizing the trees. By observing the enormous crop of berries carried by the trees this season it is readily apparent that such a condition can not continue without adding something to the soil. As many of these heavy crops have been taken from most of the trees for a number of years, it is not hard to determine the reason for the low yields of some plantations compared with former seasons.

During the coming year several more of the imported coffees at the experiment station, including the higher priced Javas, will come into bearing. These introduced varieties will be tested by experts

and a convention of the coffee growers will be called for the purpose of considering the question of changing from growing the Porto Rican coffee to that of growing those coffees that bring the highest prices in the United States markets. The Porto Rican coffee is considered the highest type of after-dinner coffee and is much relished and brings the highest price in the Latin countries of Europe. Many efforts have been made to introduce this coffee into the United States, but without much success. The question arises whether it would be better to continue the attempts to teach the coffee-drinking public of the States to appreciate the peculiar flavor of the Porto Rican berry or whether it would be easier and a shorter method to grow the coffees that they already prefer and for which they now pay the highest prices.

SUGAR CANE.

The planting of sugar cane in the island has been largely increased during the year. These plantings are being extended almost altogether in the low ground skirting the coast line. They are extending, however, among the first range of low hills, and in sections where the rainfall is abundant and the soil fairly fertile very good canes are produced on such lands. The "central system" is growing and new mills of large capacity have been installed, while those already established have increased their machinery. Several lines of experiment should be carried out with cane, but as this crop is an expensive one to deal with and the funds of the station are limited much can not be undertaken. The station is planting some improved canes of the island and has also introduced the most promising canes of the British department of agriculture at Barbados, kindly sent by Sir Daniel Morris, commissioner in charge. It is estimated by the British department that the yields from these improved canes have increased the output of sugar on the same area about 25 per cent; doubtless an equal increase can be obtained by planting improved canes in Porto Rico. A collection of the best canes from experiments carried on by the Louisiana Station at Audubon Park have been very kindly sent by Prof. R. E. Blouin. Some of these canes have proved very good indeed for Porto Rican conditions, and a number of them, and also other canes, have been sent out to representative planters in various sections for further tests. The proper fertilization of cane each planter must study for himself, as there is quite a variation in both the chemical and physical composition of the soils planted to this crop. A scheme for testing the requirements of the cane by a system of twentieth-acre plats has been outlined by the station and a number of planters in different sections of the island have taken it up and are making an extended study of their soil requirements. A

number of the more progressive planters have a small portion of their estates devoted to experiments in cane production, it proving of great interest and value.

COTTON.

It has been demonstrated that Sea Island cotton can be grown in Porto Rico, but the extension of this crop is not making much progress. It is a plant that has grown here from the earliest times; in fact, cotton is supposed to be indigenous to the island, but it is a crop that has never appealed to the people, as there have been others that bring larger money returns. There is no doubt, however, that many of the smaller farmers can make this a very profitable industry, especially as they can employ the women and children of their families in its production. It is a crop, however, that needs fertilizers to get adequate returns, and not until our planters learn the proper use of fertilizing materials can they expect a very large income from cotton growing.

There is no boll weevil in Porto Rico, and compared with the Southern States the island is comparatively well off in its freedom from insect enemies of this plant. The cotton caterpillar is the only serious menace, and this insect can be kept in check by well-known means, provided the planter is vigilant and ready to apply his remedies when the insect comes. The cotton plant grows readily in all sections of the island, but not all sections are adapted to its profitable production. At the experiment station quite a number of experiments have been carried out with cotton in the use of fertilizers and the trial of different cottons from other countries and systems of cultivation. While the plant grows readily here, it can not be recommended, for the reason that our heavy rainfall, extending through the greater part of the island, is not conducive to the ripening of the bolls, or to their gathering and curing. Rainy weather is very apt to set in and ruin the crop, but in many sections where dry spells occur cotton can be planted during the rainy season to ripen during the dry.

RICE.

The largest importation of foodstuff in Porto Rico still consists of rice, which comes from the port of New Orleans. There is some extension of rice growing in the island upon the higher lands; practically no irrigated rice is produced. Many more acres of low ground are being put under irrigation every year and devoted to cane growing. When it is necessary to rotate this ground, or when there is a decrease in the present price of sugar, these lands will probably be devoted to growing rice, for which they are well adapted. From ex-

periments made at the station with a number of varieties, it was found that lowland rices flourish in Porto Rico. When certain economic forces work around, Porto Rico will probably be an exporter of this staple. Although labor is plentiful and cheap, profitable rice growing must be carried out largely with the use of machinery, following the methods obtaining in Louisiana and Texas.

FORAGE CROPS.

The principal forage crops of Porto Rico are malojillo and Guinea grasses. These are very rank growing and nutritious grasses, the former growing on the lowlands and the latter on the foothills and even on the mountain sides. It does not seem probable that grasses superior to these two for forage purposes can be introduced. Some experiments have been made in testing lawn grasses, of which Bermuda and grama have succeeded. Bluegrass thrives vigorously for a time, but soon dies out. A number of leguminous forage crops have been under trial as producers of forage and also for restoring nitrogen in the soil. Among these the cowpea is the more promising, making a very rapid growth and producing large amounts of forage. Moreover, this is a plant that not only adds nitrogen to the soil, but very greatly improves the physical condition. No serious insect or fungus pests have developed, and this crop is recommended for extended plantings over the island. The shelled bean may be prepared in a number of ways, and is a very nutritious article of human food. The laborers at the station are growing cowpeas in place of their native bean because of the fact that the yields are much larger in amount of food. The Florida beggarweed in the experimental plats made only a fair growth the first crop, but the second and third crops were very tall, thick, and rank. This is recommended as a soil renovator and also as a forage crop. Velvet beans make a fair growth and seem free from disease; they would doubtless do much better in sandy sections. Alfalfa grows well at the station, and may be cut every six weeks or two months. It is doubtful, however, if it is a profitable crop in a region of heavy rainfall like this. The malojillo and other grasses grow more rapidly during the rainy season, and it requires a great deal of work to keep the alfalfa clean. It is probable that this would be a profitable crop for drier sections and where irrigation is practiced. While the yields here are good, the labor necessary to keeping the crop from being choked out is very great. Some twelve varieties of pigeon peas, locally called "gandules," are under trial at the station. The seed came from India, and among them are some varieties that are superior to the gandule now grown in the island. This pea is grown extensively in some sections, and adds very largely to the food supply of the people. Of the seed of the

new varieties grown at the station, a lot has been sent out to different sections for trial. It is hoped to secure varieties that will produce a larger amount of shelled peas. Experiments are also under way with this plant as shade for pineapples and for young orange trees in the earlier stages of their growth. The plant grows from 5 to 8 feet high, and besides affording shade also stores nitrogen. The station is also growing and sending out among the planters a large white bean known as "sword bean." This is a very hardy plant, and will grow even in sod with rank-growing grasses. It has been planted in malojillo grass with success. In such cases it makes a better balanced mixture for hay or green forage, and also improves the soil to such an extent as to increase the crop of malojillo. It is a plant well worthy of more extended cultivation. Besides the introduction of new legumes, some of the more promising native ones are being bred for the purpose of increasing their productivity.

FIBER INVESTIGATIONS.

The experiments with fiber plants are being continued and a number have been sent to Paterson, N. J., for extraction. A machine has lately been devised that will easily handle the maguey. A shipment was recently made to Paterson of maguey leaves for trial. The machine cleaned them well and the fiber was reported to be of very good quality. However, as the yields were comparatively small as compared with sisal, it is still recommended that the latter be propagated instead of the native maguey. Of the various fibers, sisal promises by far the greater returns under Porto Rican conditions. In cooperation with the insular government several thousand plants have been imported and planted. Funds are available under an insular appropriation for securing a much larger supply, and 100,000 more have just been imported. It is hoped to secure a great number of sisal slips as soon as possible in order to put the industry upon a commercial footing in Porto Rico. While other fibers, as maguey, sansevieria, and abaca, will grow in favored sections of the island, the yields are not to be compared with those obtained from sisal. Ramie grows well at the station on heavy clay soils in a damp situation. A plat of this fiber has yielded continuous cuttings for several years and remains healthy and vigorous.

A great many palm-fiber hats are made in Porto Rico, giving employment to many women and children in the weaving. A firm has recently established factories at Aguadilla, Mayaguez, and Cabo Rojo, employing several hundred women in the manufacture of Panama hats. The fiber is imported from Central and South America in the raw state and made up in Porto Rico for shipment to the States. Labor of this class is plentiful and cheap in the island, and it is very

desirable that the raw material be produced here in sufficient quantity to supply the demand. The station has a few plants of the jipa-japa palm under experiment, and from the results reached it will grow readily in the island. At the request of Governor Winthrop efforts are now being made to import this palm for distribution in different sections where hats are made, so that the weavers may be provided at all times with a plentiful supply of raw material at hand.

FORESTRY INVESTIGATIONS.

A great deal of the uplands in Porto Rico have been deforested and many valuable woods destroyed. This has been done largely for the purpose of obtaining charcoal, and the value of this product has been in no way commensurate with the values that could have been obtained had the trees been allowed to reach maturity. One of the more important lines of agricultural work in Porto Rico is that of reforesting these areas. About three years ago the experiment station planted one of these barren hills to the various economic trees of the island, as well as some imported from other tropical lands. With the exception of the eucalyptus, none of these trees have made a satisfactory growth upon this hill. Where the conditions are poor, but typical of such areas, it has been found necessary to change the procedure in reforesting this plat, and bananas and various leguminous trees of the island and other tropical countries are now being planted. Nature, in reforesting an area, sends up first a growth of plants that are of little value from an economic standpoint, but these seem to pave the way for the growth of more valuable trees and shrubs. The station experiments indicate that in growing economic plants in the Tropics more attention must be given to the questions of shade and wind-breaks. (See p. 21.) Not only is this true of certain fruits, as the orange, but also of hardwood trees. After the growth of the bananas and the softwood legumes has reached a stage where they afford wind-breaks and a certain amount of shade other trees will be planted.

MISCELLANEOUS NOTES.

The station has carried on cooperative work with the insular government in the introduction of fibers and the enforcement of the fertilizer and plant inspection laws. Some work has been carried on with different bureaus of the United States Department of Agriculture. The station is also cooperating with different planters in several sections of the island in the introduction of new economic crops and in the use of fertilizers. In the introduction of new crops, the station furnishes the plants only, supervising the work and making notes on the progress. In fertilizer experiments with planters the

station furnishes the fertilizers and plans the work, and members of the staff visit it from time to time and take notes. Such demonstration work is the best means for reaching a great many of our planters with improved methods. Agriculture in the island is in a primitive condition, and field demonstration proves the most effective means of instruction. Travel during the year has been confined to the island and many sections have been visited by the several members of the station staff. Visits from plantation to plantation have been made and demonstrations carried on in spraying, budding, fertilizing, and laying off farms.

The station is in urgent need of more funds and should be placed on a footing to receive the income granted the State stations under the Adams Act. A laboratory should be fitted up and a chemist added to the staff before the work in certain lines can be carried further. Moreover, it is highly desirable that more instruction be given planters in regard to the needs of their soils and their fertilization.

REPORT OF THE HORTICULTURIST.

By H. C. HENRIKSEN.

As most of the horticultural experiments now under way are planned to continue over a long period, there are naturally not many results to be reported upon at this time. The scope of the work is already too large to be successfully carried on with the present means and facilities at hand, nevertheless there are urgent calls for extension in many lines.

The work carried on at the station consists mainly of testing the adaptability of economic fruits; introducing and testing new varieties; selecting superior varieties found on the island; methods of propagation, planting, and fertilization; experiments in shipping fruit to distant markets, and the distribution of seeds and plants of varieties which in the station trials give promising results. As there has been no skilled help available and only the labor of four peons^a allotted for this work, it is obvious that in order to reach results in some lines other subjects can receive but cursory attention. The work enumerated above is supplemented by experiments conducted in various places on the island in cooperation with progressive planters.

The following plants under investigation have yielded results worth recording:

PINEAPPLES.

All the varieties of pineapple under experiment have fruited this year, producing a number of interesting types, all of which will have to be tried further before specific recommendations can be made. The Ruby, a variety from Jamaica, is the most promising of all the less-known kinds tried. The Variegated Lajas, a variety found by the writer in a field near Lajas, has produced fruit this year. This is a strikingly handsome plant, the leaves being variegated and of a much brighter hue than the Variegated Cayenne. The variegation is, however, not in the plant alone, but also in the fruit, making it very valuable for decorative purposes, while the quality is equal to that of the ordinary Cabezona. While this is the only new variety given a name, there are a number of others under observation. Pineapples here are not readily classified because of the great local variation. We have as yet only four named varieties, but there are many distinct types which are now being collected for the purpose of naming, if

^a Common unskilled laborers are generally known as peons in Porto Rico.

they should prove to be stable. Names can not generally be relied upon here, but that is common to all of the varieties in the West Indies; for instance, here the Cabezona of Lajas is different from the Cabezona of Bayamon. Plants from here sent to Dominica were on fruiting classified with the Bullhead variety of that island.^a But the Bullhead as received from Jamaica is very different from the Cabezona. The Pan de Azucar, sent from here to Dominica, is described as being the same as Black Antigua, but plants here received from Antigua under that name are quite distinct from our Pan de Azucar.

Experiments in methods of planting, amount of fertilizer, and most favorable time of applying are under way, but not far enough advanced to report upon. The most practical side of that work is being studied in large fields in cooperation with planters. From the thorough studies by the Florida Experiment Station in fertilizing it seems to be well established what the plant needs.^b Here the soils are very different, and it is of immediate importance to the individual grower to find out how much fertilizer he can economically apply and when to apply it. The influence of soil and fertilizer on the quality of the fruit is also being studied.

For years it has been generally believed that the Cabezona pineapple could not be successfully shipped from here to the States. Shipments have been made every year for a number of years, and while they were often more or less successful, the results were oftener negative. This seems to have been caused by three things—rough handling, bad packing, and wet seasons. The past season was favorable for shipping, and pines packed in the field, carried in ox carts to the train, and on the train to the seaport, and not unpacked before reaching New York two weeks later, were in fairly good condition upon reaching destination. That the percentage of rot can be minimized was thoroughly demonstrated in several experiments at this station. On March 24 two barrels, each containing 15 pines, were shipped to a New York commission house. Of these 3 per cent were spoiled; the rest were sold at 50 cents apiece. On May 14 nine crates and 3 barrels, containing in all 141 pines, were shipped to New York. Of these from 8 to 9 per cent were lost and the rest were sold at 30 cents apiece for the barrel-packed pines and 40 cents for the crate-packed, and other experiments gave similar results. Barreled pineapples shipped to Boston and Washington were reported as received in perfect condition. The regulation Red Spanish crates were used this year by firms shipping from Lajas, but they were found to be unsuitable for the Cabezona pine, and experiments were made to

^a See Dominica Station Report, 1904-5.

^b See Florida Experiment Station Bulletins Nos. 50 and 80.

devise a crate of more suitable dimensions. The fancy crate of Florida was tried also and found unsuitable, but a crate measuring 16 inches wide, 14 inches deep, and 30 inches long will hold 8 pines weighing from 6 to 12 pounds, packed crosswise, 4 on each side of the partition. The larger sizes will pack well without the use of excelsior, but for the smaller some excelsior will be necessary on the top. In order to fill out the entire width of the crate the fruit stalk may be cut off longer on the smaller pines and shorter on the larger. It is not good practice to break the Cabezona like the Red Spanish, because the Cabezona belongs to the class of pines the stems of which break off in the fruit, leaving a cavity, and often deep cracks in the flesh, in which decay starts almost at once. If the fruit could be kept long enough after cutting to let the stem dry it would be possible to break it off without injury, and it would be an advantage, because in rough handling the stem is often pressed up into the fruit. But unfortunately this can not be done, as was shown in the lots kept out of every experiment, in which nearly all the fruits were in bad condition, while those shipped were reported perfect. These results also confirm the experiments of former years.

Experiments were also made in dipping the fruit in solutions like ammoniacal copper carbonate and a weak dilution of formalin, as well as dipping the ends of the stems in melted paraffin, but none of these treatments were of any benefit, since when well handled the fruit kept perfectly without treatment. The rough exterior of the pineapple is deceptive, many people thinking that it does not need to be handled as carefully as fruits with a smooth skin. This is, however, a great mistake. Bruises are readily caused by scratching, squeezing, or bumping, especially in large, loose-fleshed pines like the Cabezonas.

MANGOES.

More mango trees have been planted in the orchard, and also about 15 acres in another part of the station grounds. (Pl. I, fig. 1.) More inarched plants have been received from the United States Department of Agriculture at Washington, and those received last year are in good condition, although they have made but slow growth. Large trees budded and inarched last year are making very rapid growth and will soon yield considerable budwood. While it has been impossible to devote much time to propagation, all the different methods described by writers on this subject have been tried, and there is no question about the feasibility of propagating the mango here. (Pl. I, fig. 2.) It may be stated that some varieties are much more subject to mango blight than others, which fact should be considered when selecting seeds for a nursery, because trees on which the young shoots and the leaves in all stages are continually killed back make but slow

FIG. 1. A TYPICAL MANGO TREE IN FULL BEARING.



FIG. 2.—INARCHED MANGOES, 1 YEAR OLD.





FIG. 1.—TRANSPLANTING AVOCADOS WITH A BALL OF EARTH.



FIG. 2.—BANANAS GROWN AS WIND-BREAKS FOR CITRUS FRUITS.

growth and are extremely difficult to bud. This same factor should also be considered in selecting budwood from improved varieties, for although the disease can be kept in check by spraying, it needs no argument to convince a Porto Rican planter that spraying is a very costly and often too costly an operation here. All of the better varieties growing in Trinidad and Martinique have been ordered and may be expected at any time.

AVOCADOS.

The last unoccupied land in the orchard has this year been planted to avocados (Pl. II, fig. 1), some of the better varieties found on the island here being collected and budded in the nursery. Several methods of budding have been tried, and while almost any method is fairly successful on the avocado, the shield bud gives uniformly good results and will probably be largely employed because it is familiar to most growers.

CITRUS FRUITS.

As the list of varieties tested at the station had become more than 100, it was found necessary to take out a large number of the citrus trees planted in the fall of 1903. These were planted on the plan of 12 of each variety, which is now reduced to 3 or, in some cases, 5. In planting trees the old method as described in last year's report has been used, which, of course, necessitated more work in the way of spraying for scale insects and other insect pests than could be given with the amount of help allotted, and while most of them would have made trees in time, it was one of the cases where it was cheaper to pull the trees up and replant. The new trees are making good growth and are not being injured by high winds, as there is a row of bananas planted between the rows of orange trees (Pl. II, fig. 2); neither is the foliage being injured by leaf-eating insects, as the soil is constantly cultivated and no weeds left to harbor these pests. Scale insects will, of course, have to be fought, because there are old trees left to infest the new ones; but under the improved conditions it is hoped that the fungi which destroy scale insects will be able to nearly keep them in check.

Most of the varieties first planted are fruiting this year. On account of the poor condition of the trees the fruit is, of course, not of good quality, but it gives some indication of what may be expected. The two varieties of navels, Thompson and Washington, were last year suspected of not being true to name, which is fully confirmed. Some of the Asiatic varieties received from the United States Department of Agriculture are also fruiting, but it is yet too early to judge of the quality. Some very desirable local varieties have been found,

of which two are worthy of special mention. One entirely seedless, found near Mayaguez, is a very promising orange, and one perfect navel, also entirely seedless, was found near Penuelas and budded at the station under the name of Penuelas Navel.

Extensive fertilizer experiments are being conducted in cooperation with planters. One series is for the purpose of showing how much fertilizer can economically be applied to a tree at a certain age and a certain size in a certain soil. These experiments are open to any planter on the island, the horticulturist furnishing the plans and keeping notes on the experiments, while the planter furnishes any brand of fertilizer which he may select, provided the formula is suitable, applying it and cultivating the trees in the usual manner. The practical result of this is obvious, if trees at a certain age produce a certain amount of growth and fruit with an application of 15 pounds fertilizer, while the plats receiving 10, 20, or 30 pounds per tree behave differently, the results will indicate which amount is the most economical to apply.

Another series of experiments is expected to show which are the best forms and amounts of the different fertilizer ingredients for the production and growth of fruit. These experiments are conducted on four different places widely apart, each experiment consisting of 9 to 14 plats of 25 trees each. The different forms of nitrogen, potash, and phosphoric acid are being used and mixed according to formulas which have been found suitable in other countries.

Most of the oranges produced in Porto Rico come from the mountain districts, where the trees are neither cultivated nor fertilized. While the fruit is often of very good quality, a great portion of it is not very firm and does not ship well. Experiments are now under way in which such trees are being fertilized and cultivated, and in some places with the special object to show the influence of potash on the shipping quality of the fruit.

Although the results of these experiments will not be available for a long time, they are of immediate value in an educational way, as they give an impetus to independent thinking and experimenting.

CACAO.

Some of the varieties of cacao imported from Trinidad and planted in 1903 are now fruiting, but it is difficult to secure sound fruit on account of the pod disease, which it has been impossible to keep in check for lack of available labor for spraying. If this disease can be kept in check without too great expense there seems no reason why cacao should not be grown here more extensively. The problem to be solved is to determine if picking and burning the diseased pods and spraying can be done so as to make a profit under present conditions.

GRAPES.

Many varieties of grapes are being tried here and others have been observed in other parts of the island, and the following facts may be noted: Phylloxera seems to be absent, but mildew attacks all varieties. Some varieties seem much more resistant than others and should therefore be selected and planted in locations to which they are adapted. The question of selecting varieties for localities is usually lost sight of. If a variety succeeds well in the cool, moist mountain districts, it could not reasonably be expected to succeed in the hot, dry plains near the seacoast. With well-adapted table varieties and judicious spraying, grape growing could no doubt be made profitable. It must not be forgotten, however, that local experience is necessary in order to succeed. The experienced grape grower from California or France would have to unlearn some of the theories on pruning, because here the *Vinifera* grape does not conform to rules. After pruning, the canes usually die back, and it is therefore impractical to cut the spur, and even in half-long pruning it is not unusual to lose the whole cane and consequently that year's crop. A system of horizontal overhead trellising with long pruning would seem to be best adapted here.

MISCELLANEOUS NOTES.

The following may be briefly noted at this time:

JACK FRUIT (*Artocarpus integrifolia*) has made very rapid growth, and the trees are all healthy. Seeds will be introduced for distribution as soon as possible.

LOQUAT (*Eriobotrya japonica*) is making a rapid growth in the orchard, and bearing trees, from seeds introduced from Spain, have been noted in the mountains between Yauco and Lares. The fruit in that case was small and of no great value, but judging from the behavior of the trees the improved varieties ought to be introduced at once.

CINNAMON (*Cinnamomum zeylanicum*?).—The tree in the orchard was this year trimmed and the trimmings stripped. The product is somewhat too bitter and not aromatic enough in the raw state, but it imparts an excellent flavor when used in cooking. As the tree is a very vigorous grower it would seem to be worthy of cultivation, at least for home use.

GUAVA (*Psidium* sp.).—All the varieties in the orchard fruited this year, but unfortunately the mummy disease, which they were not thought to be subject to, has attacked all the varieties; even the sour Guisaro (*Psidium molle*) is not wholly immune, although it is more nearly so than any other variety under trial.

APPLES.—Both the Early Harvest and Red Astrachan have borne fruit this year, which may be considered very fair, as they were not planted until April, 1905. The fruit was of fair quality and not the least diseased. A fungus disease noted on the leaves last year is not doing much damage now.

PEACHES.—The peach trees, which were also planted in April, 1905, are making very good growth and several trees of the Peen-To, Jewel, and Waldo varieties early in the season produced fruit which was of first-class quality.

The KEI APPLE (*Aberia caffra*) and VOA-VANGA (*Vangueria edulis*) and Waldo varieties early in the season produced fruit which was be said about the quality.

SEED AND PLANT DISTRIBUTION.

About 1,000 packages of seeds and plants have been sent out to planters on the island and to correspondents in the United States and abroad. Among the special distributions that were made should be mentioned divi-divi, rozelle, lleren, guava, amatungula (*Carissa arduina*), and downy myrtle (*Myrtus tomentosus*). A large number of requests for plants of various kinds are received throughout the year and in that way the surplus material of many under experiment is being distributed before it is actually tested at the station, as well as a number of well-known economic fruits and shade and flowering plants.

REPORT OF THE ENTOMOLOGIST AND PLANT PATHOLOGIST.

By W. V. TOWER.

The writer was appointed a member of the station staff in the spring of 1906. The work which was taken up had been for a year without anyone in charge, and it was therefore necessary to get the threads together before considering any extended line of investigation. Many trips were made to different plantations for the purpose of learning the needs of the planters and advising with them in regard to methods of combating the various insect and other pests with which they have to contend. Porto Rico is not infested with many of the diseases of plants that have wrought havoc in other countries. This is due partly to isolation and partly to the fact that extended plantings of some of the present economic crops date only from the time of the American occupation, some eight years ago.

DISEASES OF CITRUS FRUITS.

By far the larger part of the oranges shipped from the island are wild fruit. These grow in sheltered valleys or groves of natural forest, where they are protected by shade and from the winds. Upon such trees scale is absent or does not seem to thrive. On the cultivated groves, especially where there is no shade or wind-breaks, scale is increasing in amount, and the battle to keep it in check is becoming more serious every year.

Scab infests nearly all the sour orange nursery stock and in many nurseries it is spreading to the budded trees, especially the grape fruit.

In a recent trip through the orange groves there appeared to be very little foot-rot or gum disease. These diseases, which resemble each other in certain respects, are probably due to physiological disturbances. The best treatment is to thoroughly clean all infested areas and apply a fungicide, being careful not to use a solution which will in time weaken the tree, thus causing its death.

The red or circular scale (*Chrysomphalus ficus*), is becoming rather serious in some of the orange groves. Kerosene emulsion does not seem to kill it, but lately we have found a parasitic fungus which is

likely to hold it in check wherever the conditions are favorable. A sample of this fungus has been sent to the Department of Agriculture at Washington for determination.

The purple scale (*Lepidosaphes beckii*) is the most serious pest to the orange growers. This insect has been reported in all the groves in the Bayamon district, and on recent trips to Ponce, Yauco, and Pennelas it was found established in planted groves on the seacoast plains, but was not causing any serious trouble, as it seems to be held in check by fungi. In the mountain districts where no budded trees have been introduced the purple scale has not been found.

In the planted groves various soaps, kerosene, and crude oil emulsions, and resin and potash washes are being used. In inspecting the groves it is readily seen that these sprays are not giving satisfactory results. Experiments are now being carried on in the station grove, as well as in cooperation with planters, testing various insecticides and fungicides.

Lime and sulphur (25 pounds quicklime, 25 pounds flowers of sulphur, and 75 gallons of water) is giving promising results and does not injure the foliage, except occasionally very tender growth. One advantage of this mixture is that the tree appears white after spraying, thus showing just where the spray has touched. Of course it would not be well to use it on nearly ripe fruit, as that would necessitate washing. Hydrocyanic acid gas has been tried, but from the limited experiments it is too early to draw any conclusions. In many of the groves where the natural conditions are favorable the scale is held in check by parasitic fungi. Experiments are now under way to introduce fungi where they are not present. Fungi develop in localities where the prevailing winds are broken by wind-breaks, and it is well recognized that unless shelter from the winds is present it will be necessary to provide wind-breaks by setting out such plants as are best suited to the locality. In heavy soils bananas are being used extensively, while in some of the lighter soils the pigeon pea is giving good results.

The "cuelno," or May beetle (*Lachnostenus* sp.), and the orange leaf-weevil (*Diaprepes spengleri*) are not abundant in orange groves which have been under clean culture for at least one season. In some of the new groves which have been planted in cleared pasture lands the beetles are very disastrous. Hand picking is often practiced, but excellent results have been observed by spraying with arsenate of lead.

The brown or hemispherical scale (*Saissetia hemisphaerica*) is at present not causing any trouble. In some of the orange groves and coffee plantations there has been observed a fungus which seems to be doing good in checking this scale.

The West Indian peach scale (*Diaspis pentagona*) is very abundant all over the island, infesting peach, plum, mulberry, papaw, castor bean, and other plants. This is a very troublesome pest, as it does not readily yield to sprays unless strong enough to injure the foliage of the host plant.

PINEAPPLE DISEASES.

The pineapple in Porto Rico is comparatively free from diseases or insect pests. During the last year several million plants have been set, the slips coming from Florida and Cuba. From the way the industry is growing and the many sources from which slips are brought into the island, we will no doubt be troubled with some serious diseases or pests in the future.

A grower who has been planting the crowns from the fruit used at a pineapple cannery has had some trouble with the plants rotting soon after being set. It was found advisable to allow these crowns to dry some eight or ten days before planting. After such treatment the losses were reduced very materially. The trouble is first noticed by a rotting of the lower leaves and underground parts, later on extending to the center leaves, which usually remain green for some time after the roots and lower parts are entirely decayed. The exact nature of the trouble is being worked out, but it is not probable that it is a specific disease of this plant.

BANANA DISEASES.

A number of diseased banana stalks have been sent in to the station from some of the coffee plantations where bananas are used for shade. The same disease has also been found at the station, and judging from the damage it may become a serious problem. The infection seems to start from the soil and is probably of bacteriological origin. Upon examining the trunk disease-darkened areas were found which extended from the base of the plant to the apex. Several plant cells which were broken gave off a very disagreeable odor. A similar disease has been reported from some of the Leeward Islands and is being studied by the British stations.

PINEAPPLE INSECTS.

Mealy bugs, attended by ants, in certain localities are causing some damage to pineapples. The ants build galleries of sand in the crown, thus retarding the growth of the plant. Resin wash has been advised and used with good results. Brown ants are not causing any serious trouble in the orange groves which are kept in thorough cultivation,

but on a recent trip the writer found one grove in which pines were planted between the rows, and here the ants were eating the young foliage of the orange trees.

COFFEE INSECTS.

The coffee leaf-miner (*Leucoptera coffeella*) is causing a considerable number of leaves to fall in some plantations. The writer has observed spots where the trees were almost denuded. The parasites do not seem to be holding the insects in check, as they were reported as doing in the previous report.

The coffee leaf-weevil (*Lachnopus* sp.) has been sent to the station from plantations in the neighborhood of Arecibo. The adult insect feeds upon the leaves, reducing the leaf surface at the time when the fruit is setting. Hand picking is practiced with apparent success. This work is usually done by women and boys, receiving so much per quart for picking.

Inga laurina and *Inga vera* are used extensively as coffee shade. On a recent trip into the mountains we found that many of these trees are killed (especially in certain areas) by a very small boring beetle (*Xyleborus* sp.), which is similar to the one that infests the cocoanut palm. On examining the wood, we found it was literally honeycombed. This insect is being studied, and until more is known concerning its life history we are recommending the washing of the trunks with whitewash and carbolic acid. This mixture has been used successfully as an expellant.

SUGAR-CANE PESTS.

The diseases and insects of sugar cane are not causing the planters any serious trouble. There are, however, a number of borers which will in the future cause serious trouble, as cane is being planted on the same land year after year. This constant planting tends to increase disease. Experiments are now under way to determine the best methods for combating these insects. The insect that is causing the most damage to cane is the large borer, *Diatraea saccharalis*. In planting new fields of cane planters are advised to soak their seed for twenty-four hours in lime water in order to kill all borers they may contain. Some excellent results have been obtained by this method in reducing the number of insects, even on land that has already been infested. The canes that are to be planted are placed in a tub or tank, water turned on, and several shovels of lime thrown on top. This is allowed to stand twenty-four hours, when the canes are taken out and planted. Not only is the borer destroyed, but in comparative experiments made at the station seed so treated sprouted quicker and the number of sprouts sent up was greater.

REPORT OF THE COFFEE EXPERT.

By J. W. VAN LEENHOFF.

There is an improved condition among the coffee growers as far as production is concerned. This has come about by recovery from the results of the severe storm of 1899 and also from the fact that better methods of tillage are being followed on many plantations. There is a very heavy crop on the trees in nearly all sections of the island this year which will materially help the coffee planters. Prices remain about stationary, and most of the product is still sold in France, Spain, and Cuba. Although efforts are continually being made to influence the American taste to the liking of Porto Rican coffee very little progress has been attained.

EXPERIMENTAL PLANTINGS.

The work of the experimental tracts, except for the beginning of grafting in the new coffee and for some fertilizer experiments in both the old and new coffee, has been restricted to the care of the plantings in accordance with experiments outlined in previous reports (Pl. III, fig. 1). Some few varieties from other countries have been added to the collection. Through the kindness of Mr. Moy, French consul to Porto Rico, the French Government has sent the station a collection of coffee plants from the colonial agricultural establishment at Nogent-sur-Marne, which is of great interest and probablé value in the work. There have also been received from Mr. George Loutrel Lucas, of Jamaica, some seeds of the famous Blue Mountain coffee of that island. These, added to the Javas and other coffees previously received, make a very interesting collection of the best coffees of the world. The Philippine and Hawaiian coffees that have come into bearing are no doubt similar in flavor to the Porto Rican coffee and seem to have no advantage over it. Ceylon coffees that have ripened are superior in flavor, and from trials made in the cup it is probable they will be a valuable introduction in our coffee plantations.

The object of securing the best coffees from various countries of the world is not for the purpose of having a large collection of varieties, but for the purpose of testing these with a view of growing those coffees that bring the highest prices in the markets of the world. The soil, altitude, and climate of Porto Rico seem to be well adapted to the growing of coffee, and as far as our experiments indicate, there seems no reason why Porto Rico can not grow the very finest berries, not only in point of appearance, but in flavor and aroma. If after testing these varieties they are found inferior to the native coffee, they will be discarded and destroyed. If, on the contrary,

they prove superior to the coffee already grown in the island, it is the purpose of the experiment station to distribute them as rapidly as possible among our planters, with a view to their early introduction in a commercial way. If Porto Rico coffees bring 10 cents per pound in the markets and other coffees bring 20 cents, then the first duty is to learn the secret of the better production and follow it as quickly as possible. If the market demands a certain flavor and will pay the highest prices for the berries that carry it, then we should, above everything else, produce that coffee.

While seeking to produce coffee of the highest quality, effort should also be made to increase the yields. The average production per tree and per acre is far below that of some other coffee-producing countries. (Pl. III, fig. 2.) The reason for this lies primarily in the soil, and effort should be made to remedy this defect to the end that the present production per unit may at least be doubled. With this object in view the experiment station is carrying out a number of series of experiments in fertilizing coffee trees. Various mixtures of fertilizers are being employed and in different forms; also experiments are under way using pulp from the coffee mills and also in using the deposits of bat guano found in many of the caves in Porto Rico. A number of plans have been outlined for different planters for carrying out fertilizer experiments for themselves. Some of these are comparisons of commercial fertilizers with a home-made fertilizer, made of bat guano and potash salts. Some of the guanos found in the caves run from 2 to 3 per cent and over in nitrogen and 10 per cent in phosphoric acid. With the addition of potash these make complete fertilizers that are richer in the elements of fertility than some of the commercial fertilizers sold on the island. On many of the plantations these bat guanos are found ready at hand.

Coffee blossoms in Porto Rico at different periods, according to altitude and locality. On the north side of the central range of mountains, which runs from east to west and south of the middle line of the island, coffee blossoms a month or more earlier. The period on the experiment station tract ranges from February to May, consisting of one principal blossoming and followed by one or more smaller blossomings. The principal blossoming decides whether we shall have a good, average, or poor crop. About seven months after the blossoming the berries ripen. The harvest begins in September and lasts until January, during which time about ten pickings, at intervals, are made.

MALTING OF COFFEE.

The harvest time of coffee in Porto Rico falls in the rainy season, September to December, and several of the smaller planters, lacking artificial means of drying their coffee, are entirely dependent on the



FIG. 1. COFFEE SUBSTATION, LA CARMELITA.

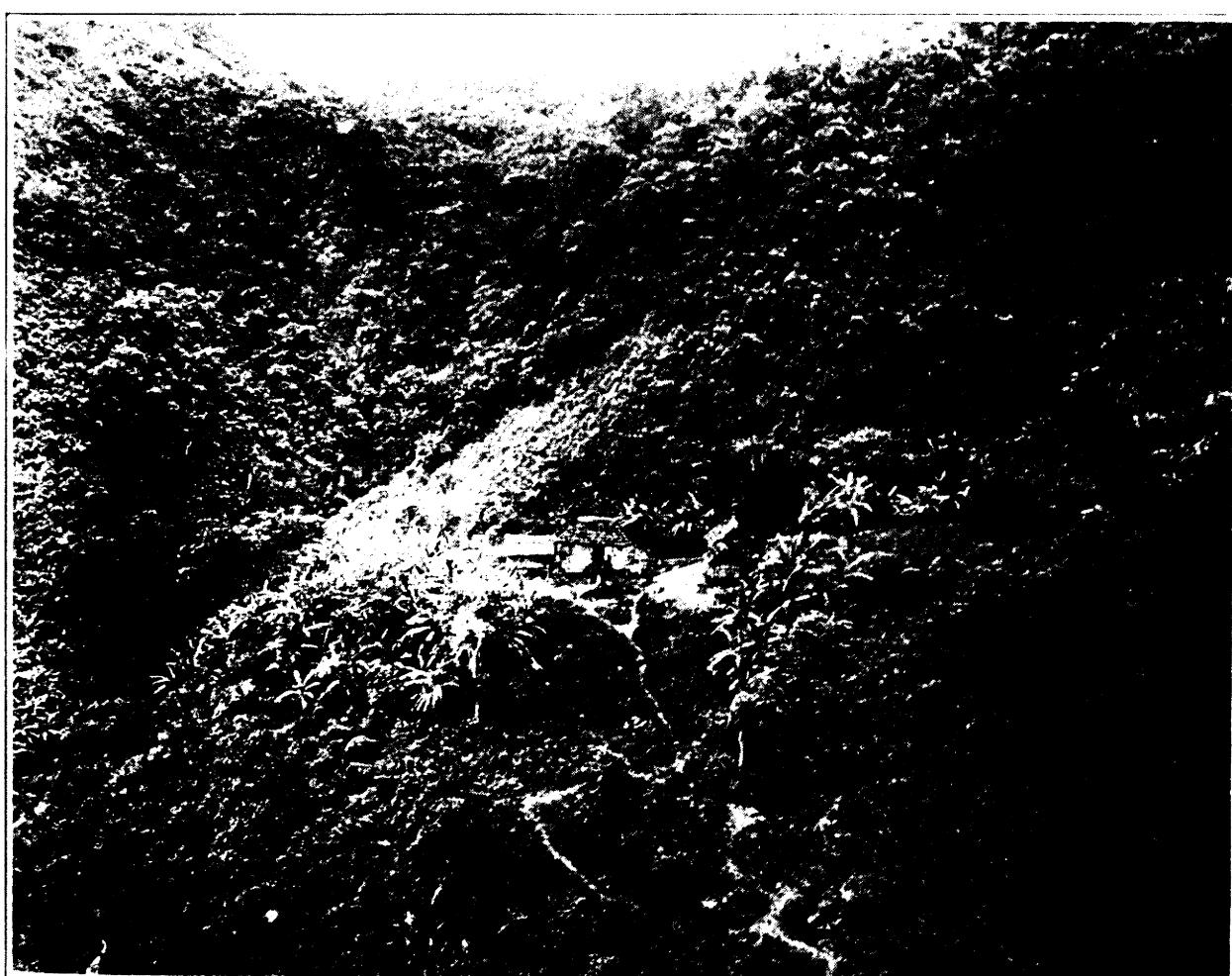


FIG. 2. - A NATIVE COFFEE PLANTATION AND RESIDENCE.

sun. When the sun does shine during several days in succession, as often happens during the rainy season, the wet coffee begins to sprout, and through lack of proper handling rots, developing a very bad smell. With a view of determining how long wet coffee could be kept without damage to quality and also to determine if the sprouting process influenced the flavor, the following experiments were made:

December 30, 1905, fermented and recently washed coffee in the parchment skin was put in a heap on a cement floor in a basement very much resembling a malt cellar. The heap was turned daily.

January 23, 1906, the first grains began to sprout, and the heap was spread out about a foot deep and turned daily.

February 23, 1906, all the grains had sprouted, and the sprouts had about the same length as the length of the grain. The whole was now dried in the ordinary way and hulled.

During the sprouting process, and before turning, the upper layer, having become dry, was sprayed with water of ordinary temperature. The sprouting process was very irregular, and as soon as some grains had developed sprouts of the length of the grain, these were taken out and dried. Not the least bad smell was observed during the whole process, lasting fifty-six days.

Of the coffee prepared thus samples were sent to different consumers, roasters, and dealers, and their opinion requested. Messrs. F. A. Cauchois & Co., of New York, wrote as follows: "Your 4-pound sample of coffee was received to-day, and I roasted part of it and found it a fine-looking and nice-tasting coffee." Dr. Walter H. Evans wrote: "I received some time ago a sample of malted coffee. We have tried this and like it very much." And later, "Those of us who have tried the coffee like the improved flavor very much." Other recipients communicated verbally and made similar statements. To the writer personally it seemed that the flavor of the coffee prepared thus was finer, and that the bitter taste so much complained of had disappeared.

The result of the experiment can be regarded as favorable, as it seems to prove that coffee can be kept in a wet state and allowed to sprout for about two months without damaging the quality. It is to be regretted that lack of instruments did not permit observations of temperature and weights and mechanical and chemical changes. I would recommend that the experiment be repeated with all necessary facilities for observations and comparisons.

DISEASES AND INSECT PESTS.

Leaf weevils (family Otiorhynchidae) continue to do considerable damage, and are most abundant in the neighborhood of higuerillo trees (*Vitex diraricata*). It seems that they breed with preference on those giant trees, from which they occasionally drop on the coffee

standing underneath, causing a circle of destroyed coffee trees around the higuerillo.

Leaf-miners (*Leucoptera coffeella*), although plentiful, do not seem to be so abundant as last year. Experiments with sulphur mixed with the soil around the roots did not give any result at all. Hand picking had to be abandoned, but the observation of last year that the better the soil the less the plant suffers from attacks of the leaf miner was made use of this year to try fertilizers. A field of heavily attacked trees of a neighboring plantation was selected. It contained 584 three-year-old trees with hardly a leaf left on them, those that were left being filled with the leaf-miner. The whole field presented a barren aspect. Between January 29 and February 1 the trees were fertilized as follows:

Fertilizer experiment against coffee leaf-miner.

Number fertilized.	Stable manure.	Coffee pulp.	Lime.	Nitrate of soda.	Super- phos- phate.	Muriate of potash.
	Pounds.	Pounds.	Pound.	Ounces.	Ounces.	Ounces.
41 trees.....	5	5	0.5	1	1	1
73 trees.....			.5	1	1	1
470 trees.....				1	2	1

Before the application the ground was hoed for about 2 feet around the trunk of the tree and the stable manure and coffee pulp worked in. The fertilizers were used as a top-dressing. On March 13 following 1 ounce of nitrate of soda was again given to each tree.

At the time of writing all the trees had entirely recuperated and had blossomed well, but it remains to be seen whether they will withstand the leaf-miner attacks until harvest.

A fungus disease was observed attacking coffee berries and apparently passing through the parchment, causing circular perforations, into the grain, in which it produced warty excrescences, rendering it valueless. The disease occurred on trees in the shade as well as on those without shade, those attacked suffering severely. On healthy trees the disease was not observed. The diseased spot on fresh berries under the magnifying glass showed distinct fungus growths, white threads, and some mushroom forms of a yellowish color very much like the *Stilbum flavidum*. The disease on the parchment and grains was observed in former years, but not in such abundance. After the blossoms of this year had fallen off, the trees observed last year to be attacked by the disease were sprayed with Bordeaux mixture, three sprayings being given at intervals of two weeks. Up to the present time no disease has been noticed on the sprayed trees.

UNIV. OF MICH.

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Issued May 4, 1908.

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

D. W. MAY, Special Agent in Charge.

ANNUAL REPORT

OF THE

PORTO RICO

AGRICULTURAL EXPERIMENT STATION

FOR 1907.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1908.

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations,
United States Department of Agriculture.]

**WALTER H. EVANS, Chief of Division of Insular Stations, Office of Experiment
Stations.**

STATION STAFF.

D. W. MAY, Special Agent in Charge and Animal Husbandman.

J. W. VAN LEENHOFF, Coffee Expert.

W. V. TOWER, Entomologist and Plant Pathologist.

M. J. IORNS, Horticulturist.

OSCAR LOEW, Physiologist.

P. L. GILE, Assistant Chemist.

E. F. CURT, Farm Superintendent.

CARMELO ALEMAR, Jr., Stenographer.

LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., January 20, 1908.

SIR: I have the honor to transmit herewith and recommend for publication the Annual Report of the Porto Rico Agricultural Experiment Station for the fiscal year 1907.

Respectfully,

D. W. MAY,

Special Agent in Charge.

Dr. A. C. TRUE,

Director Office of Experiment Stations,

U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON,

Secretary of Agriculture.



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ANNUAL REPORT OF THE PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1907

SUMMARY OF INVESTIGATIONS.

By D. W. MAY, *Special Agent in Charge.*

INTRODUCTION.

The fiscal year 1906-7 has been a prosperous one for Porto Rico, in agricultural lines especially. The total import and export trade of the island for the year was \$45,000,000. The exports included in this sum totaled \$23,257,530. This represents agricultural produce, very largely in a raw state. The exports of the island show a large annual increase since the year 1901, the exports that year aggregating \$8,583,967. The total sum for the year 1906 of both exports and imports and of each separately aggregate almost double the amount of any year in the previous history of the island. As many of the leading agricultural resources of Porto Rico, like the citrus industry, are only beginning, an increase in agricultural production may be expected to continue for years to come unless some very untoward calamity occurs.

The people of Porto Rico are studying as never before the resources of their country and the possibilities of the soil and climate. Credit must also be given to the many planters from the States who are investing their means and building homes in Porto Rico. The increase in land values is caused by the increased values produced by our soils under the improved methods that are being followed. Porto Rico is at the door of the markets of the large cities of the eastern United States, the best market in the world, with a low freight rate and no duty to pay. Her prosperity then should depend upon her own efforts and be measured by her industry.

The striking difference in the new agriculture of Porto Rico is the diversity of her crops. In the times of Spain coffee and sugar were the great staples, while no effort was made to grow even articles of universal need that were easily adapted to the soil and climate. This is still in evidence, as shown by the enormous importation of rice, as well as many of the common vegetables. However, some articles that were imports are now in the list of exports and the number will be further increased.

Besides a continuation of the work of the agricultural experiment station previously reported, several new lines have been planned and put into effect. This has been made possible by the Congress of the United States providing additional funds for maintenance, which for the coming year amount to \$9,000. Out of this sum a chemical laboratory is being fitted up and a chemist and assistant chemist have been employed. It is hoped also to add a plant pathologist to the staff, permitting the entomologist to devote all his time to that subject.

The present greatest need of the station is a suitable building for carrying on the work of its various departments. Heretofore an abandoned sugar mill that stood on the plantation when purchased for the use of the station has been employed for this purpose, but it is wholly unsuited to the requirements. A modern building situated on higher ground, with a system of ventilation and adapted to bacteriological and chemical work, is much needed. In fact, it is absolutely required before certain work now necessary can be carried further.

During the year H. C. Henricksen, horticulturist of the station, resigned to enter other service. He was succeeded by M. J. Iorns, Ph. D., of Cornell University. Dr. Oscar Loew, formerly connected with the U. S. Department of Agriculture and lately with the Imperial University of Tokio, Japan, was appointed chemist. P. L. Gile, A. B., of Harvard University, was appointed assistant chemist.

The experimental work of the station, which will be reported under separate heads and by the different departments, has been increased and extended. The tree fruits planted soon after the station was established are coming into bearing, and a number of these have been found commercially adapted to Porto Rico. In the agricultural development of the island certain crops have increased enormously, while others that have been found successful in an experimental way are being taken up commercially by various planters in different sections of the island.

SUGAR CANE.

Of the exports of Porto Rico, sugar is largely in the lead, aggregating during the fiscal year, \$14,738,572. This is over \$5,000,000 in excess of all other exports. The area devoted to sugar cane will doubtless increase somewhat for several years. The production per acre, however, is likely to show a considerable increase. This is by reason of the fact that not only are better methods of cultivation being practiced, but canes carrying a higher percentage of sucrose in the juice are being planted. The experiment station has a number of seedling canes in the experimental plats which contain from 15 per cent to 19 per cent of sucrose in the juice. The average percentage of cane now grown in Porto Rico is much below this, possibly aver-

aging around 10 per cent. These seedling canes are being sent out from time to time to different planters over the island for trial. Some are found best adapted to certain sections, while others seem superior on other soils or under different climatic conditions. The breeding of new canes is proving of great benefit to the island. Not only is the yield of sugar greatly increased by some of the new varieties, but their general thriftiness is greater and resistance to disease stronger. The largest sugar company on the island has recently employed two men to work in cooperation with the station in the breeding and disseminating of new canes.

In experiments in fertilizing cane at the station the great lack seems to be in the nitrogen content of the soil. With heavy rains and burning sun nitrogen is rapidly eliminated from the fields. On the other hand, various legumes flourish in Porto Rico and nitrogen can doubtless be grown even in connection with continuous cane culture. Owing to the profitableness of the sugar cane, Porto Rican planters employ every means to take this crop year after year from the same land. As nitrogen is by far the most expensive element of the fertilizer and apparently the one most needed, experiments are being carried out with a view of demonstrating the feasibility of supplying this element in the cane fields by the growing of leguminous crops between the rows. Of the legumes being tested, the cowpea and the sword bean are the most promising, but several years experimenting will be necessary to determine the value of the system of growing these crops on the same ground with cane. The cowpea will mature in seventy days, so that a crop can be readily grown between the rows after planting the cane and again after the last plowing.

Experiments with distances of planting in cane production are being carried on for the purpose of determining the method that will give the most cane per acre at the least cost of production. The usual practice in the island is to plant very close, 5 by 6 feet. The station's experiments have been carried on with hill planting 5 by 5 feet up to 10 by 10 feet, and also in continuous rows. For the first crop the narrow planting has given the heaviest yield. As only one crop has been harvested from these plats, figures on the ratoon crops can not be given, but the indications are that the differences in yield will be less between the wide and narrow plantings on the second crop. As the cane is an intensive crop it seems advisable to grow as much as possible each year on the same area, supplying the drafts on the soil by the application of suitable fertilizers, and avoid thereby the necessity of leaving the lands idle for a series of years to recuperate. In proportion to the development above ground the root system of the cane plant is not extensive, therefore very heavy tonnage can be taken from a small area. Our cane growers can derive great benefit from

thorough preparation of the soil before planting. Agriculture in Porto Rico has only skimmed the surface, plowing being very shallow and often with only a wooden plow. Some of the large sugar companies have put in steam plows, which are going to a depth of 8 inches or more. This is found a very profitable practice, giving large profits for the cost of the work. After the canes are planted more thorough cultivation of the surface should be given than is usually practiced. A great deal of hand labor should be supplanted with the cultivator for reasons of economy.

In planting cane it is a better practice to open furrows with the plow, it being less expensive than cutting holes with spades, as is usually done. Moreover, by this method the ground is stirred to a greater depth and a larger surface is pulverized. From preliminary experiments at the station continuous rows have given larger yields than the same number of canes planted in squares. In planting in rows canes were stuck in the ground on end, as is the usual custom. The Hawaiian system of planting the canes in lines covered entirely with earth has also been followed. This is a better practice where the changa, or mole cricket, is not too bad. Where this insect is prevalent, however, the young seedlings are liable to be cut off when they break through the ground. If the canes are planted entirely below the surface, the young seedlings will doubtless get more nourishment from them than when planted on end. Again, when planted on end the ants carry off considerable of the juice of the cutting and some of it is lost by drying out and rotting above the ground. From the one crop of plant cane the Hawaiian system gave more tonnage than the similar plats planted in the native fashion, although by the former method a small portion had to be replanted because of the ravages of the changa.

Fertilizing canes in Porto Rico will pay in nearly all cases but, owing to the variations in the soil, it is impossible to give any definite plan. The fertilizer should be applied early, and it is especially advisable to start the canes off with a readily available fertilizer. An early start and a strong one means a great deal to the cane plant. It will make a larger growth and also be able to assimilate more of the elements already in the soil if it can get a quick start. Further details of fertilizing are to be found in Circular No. 6 of this station, recently issued.

COFFEE.

The exports of coffee from Porto Rico for the fiscal year aggregated \$3,496,082. Of this amount the United States purchased only a little over 1 per cent. While practically all of the sugar went to the United States comparatively little of the coffee was sent there. This is for two reasons: (1) The duty on sugar makes the United



FIG. 1.—PREANGER COFFEE PLANTED ACCORDING TO EAST INDIAN METHOD.



FIG. 2.—TYPICAL COFFEE PLANTATION IN INTERIOR OF PORTO RICO.

States its natural market, and (2) there is no duty on coffee, and the American people do not relish the peculiar flavor of our variety. Porto Rican coffee is a very fine after-dinner coffee much relished in the Latin countries of Europe, and most of our exports of coffee find their market there. Efforts have been made to introduce Porto Rican coffee into the United States, but so far little progress has been made in this direction. It is very hard to change the taste of a people. It were better, if such a market is desired, to produce the coffee which already has an established trade with the States and which brings the highest price in that market. With this in view, the experiment station is carrying on experiments in growing the higher-priced Java coffees, which are highly flavored and command the highest prices in the States. (Pl. I, fig. 1.) From the few berries which have matured to date, it seems probable that highly flavored coffees can be grown in Porto Rico and retain the aroma peculiar to them in the countries from which they are now shipped. Whether they will continue to do so year after year is a matter for further experiment. More details of the experimental work with coffee are given in the report of the agent and expert in charge (p. 39).

Some coffee is being planted in the interior, but the extension of the industry in the island is very small and the outlook is not encouraging for the future. (Pl. I, fig. 2.) The enormous production of coffee by Brazil is not very favorable for prices of this product in the world. From statistics it appears that there is a great deal of coffee on hand in the markets, and while the Brazilian Government is holding a great deal of it with the hope of maintaining the price, unless the world's production is curtailed the price will be lower.

In some of the old coffee plantations in Porto Rico orange trees are being planted. Others are being cleared out entirely and the land devoted to pineapples and tobacco. As a rule, inaccessible lands in the interior are being planted to coffee, while the old plantations, especially where they are near the macadamized roads, are being planted to more remunerative crops. Better planting and cultivation would doubtless increase the yield of coffee. Fertilization can also be profitably practiced in some instances, especially where large deposits of bat guano are found near by. As the profits from this crop are small, planters are not inclined to expend much in commercial fertilizer. This is especially true where the means of transportation are difficult.

TOBACCO.

The tobacco crop during the past year was not as successful as that of the preceding year. This was due largely to an unfavorable season, resulting in great losses in the seed beds, which was followed by the setting of inferior plants from any source available. Altogether

the entire season was unfavorable to the production of a crop of high quality. However, the extension of this industry is shown by the crop of the coming year. A more detailed report on the handling of the crop, the curing, and fermentation is given in another section of this report (p. 16).

FIBER CROPS.

The station is continuing the experiments with various fiber crops, as described in former reports. From all considerations of soil and climate sisal seems to be the most promising. A great deal of land that is not adapted to any other purpose is suitable for the production of this fiber. With an appropriation made by the insular government the station purchased 100,000 plants and a number of them have since been sold to planters at \$15 per thousand. This sum, while very low, covers the cost of handling the plants. It is to be hoped that more lands will be set to sisal, especially the dry limestone sections that are not profitably employed in growing any other crop. The abacá or Manila hemp also grows well on the island, but requires a fertile soil such as will grow bananas. The extension of abacá cultivation is therefore not expected, as land suitable for it can be more profitably employed in growing other plants.

During the year a number of plants of Carludovica have been imported from Guayaquil, Ecnador, for introduction as a hat fiber. It is from this plant that the genuine Panama hat is made, and it is our purpose to extend its planting among our hat weavers. Besides producing many hats from a native palm, several factories are turning out genuine Panama hats, all made, however, from imported fiber.

COTTON.

Sea Island cotton is produced in some amount in different sections of the island, but there is little if any increase shown over that of the previous year. Porto Rican planters are hard to interest in cotton growing. This is due mainly to the fact that they do not understand the best methods employed in its culture. The land must be fertilized for cotton and the planter must be prepared to protect this crop from the ravages of insects, especially the cotton caterpillar, which sometimes comes in immense armies. Unless the cotton grower is prepared with a good supply of pure Paris green, his crop is liable to be swept away very quickly.

FORAGE CROPS.

Guinea and malojillo grass continue to yield the forage largely consumed in the island. It is advisable to grow other forage crops that are rich in protein in order to give a more balanced ration. For this purpose cowpeas and velvet beans have succeeded best at the station.

Alfalfa grows, but it requires constant cultivation to keep it from being choked out by the vigorous native grasses. Alfalfa might succeed better, however, in the drier sections of the island, notably on the black soils on the south side.

FORESTRY.

There exist in Porto Rico, between the low lands devoted to sugar cane and the high lands devoted to coffee, many foothills bare of trees. These lands are not very productive, yielding for the most part scanty pasturage. Many of these low-lying hills are excellent orange lands. They were formerly covered with forests which have been utterly destroyed. Owing to the heavy rains and baking sun it is a difficult matter to get these lands again set to trees. In our experiments on a very tenacious red clay hill many native and introduced species of trees have been planted. With the exception of species of Eucalyptus no satisfactory growth has been made. Of the others the leguminous species have done best.

Nature in reforesting sends up first a straggling growth of brush, which after growing for some years affords a shelter for seedlings of larger growth. It appears best, therefore, in reforesting such areas to grow at first hardy shrubs or trees like the guava, with a view of getting the ground covered with a protective crop and later planting it to the more valuable forest trees. Such a system, however, must look to the future for returns. As shown in another portion of this report, wind-breaks are necessary in the production of citrus fruits, and this is also essential with many other economic trees. Therefore, on the bare, wind-swept hills of Porto Rico reforesting with hardy trees is essential in bringing them into a condition to grow economic trees and tree fruits.

FERTILIZERS.

The soil of Porto Rico is naturally productive, but in many sections for a long time agriculture has been carried out with the object of getting continuous crops from the soil without returning anything thereto. It is not strange, therefore, that many of the lands are unproductive. However, the soils respond very readily to applications of manures and fertilizers, most of them needing the three elements—nitrogen, phosphorus, and potash. The imports of fertilizers for several years have greatly increased. The planters are finding out the value of proper fertilizers, and they are urged by the experiment station to apply such in their operations. In hardly any line of agricultural endeavor in the island can the greatest success be obtained without the application of fertilizers.

A fertilizer law which will cover the importation and the sale of all artificial manures is needed very much. Such a law was passed

three years ago by the legislature. This act was drawn up by members of the experiment station staff and was modeled on the Georgia law. It carried an expense of 25 cents per ton for its enforcement. Pressure was brought to bear on the legislature at the succeeding session by certain large interests and dealers to have cut out the clause providing for the enforcement of the law. The act now remains a dead letter and the consumer is without adequate protection in the purchase of fertilizers. In view of this fact, many of our planters are buying the ingredients and mixing their own goods. Regardless of the fact that they may sometimes buy a mixed fertilizer to advantage, they are led to the latter course because they have absolutely no protection in the matter.

The station advises planters to use as far as possible the supplies of stable manure and the bat guanos found in many sections of the island. Many analyses have been made and home-made fertilizers planned, thereby saving a great deal of money to the plantation owners.

LIVE STOCK.

The exports of live stock have been on the decline for several years, while the average value in the island has greatly increased. As agricultural industries extend and the country becomes more prosperous the demand for animals naturally grows. Some improvements in the horses by the selection of sires and by the importation of breeding stock from the States are noted. Horses with due care can be acclimated, and the Porto Rican horse adapts itself very readily to improvement by crossing with the lighter types of horses from the States, as the standard-bred or the American saddle-bred horse. The native horse is one of great stamina and some are quite handsome. They should, however, be bred for greater size. The average price of horses in Porto Rico has more than doubled in the past few years. Some planters are going in for horse and mule breeding with every assurance of success. A great many mules have been imported into the island during the year for working in the cane and tobacco plantations. Also some jacks and jennets for breeding purposes. Mules are well adapted to the work in Porto Rico and stand the climate very well.

CATTLE:

Formerly large numbers of cattle were exported, principally to Cuba for work in the cane fields. This trade has fallen off to less than half since 1901. The consumption of meat on the island has doubtless grown with the increased prosperity, and the extension of the sugar-cane planting has taken a great many cattle for working purposes. In Porto Rico cattle are considered first as beasts of burden, and they have been selected and bred with the object of producing work animals. Now mules are supplanting cattle to a certain

extent, while meat and milk products have increased in value. To help supply the latter products cold-storage meats and tinned milk, cream, and butter are imported from the States. Porto Rican cattle have a splendid physique, and by selecting and breeding with a definite end in view doubtless earlier maturity could be obtained and the milking function greatly increased. It is a question whether it is best for a planter to improve his cattle by careful selection of native stock or by the importation of improved breeds. If the tick fever occurs on the island it is in a mild form and cattle can become acclimated without severe losses where due care is practiced. On the other hand, the ticks are very fond of the long-haired imported cattle, and it takes constant and unremitting care to keep these insects from sucking the blood to such an extent as to produce an emaciated condition in such animals. If pure-bred cattle are brought into the island the importer should be prepared to give them the very best of feed and attention and to keep them at all times comparatively free from ticks. Unless the importer is prepared to give imported cattle good stabling, feed, and water, and grooming and cleaning from ticks, he had better not bring them to Porto Rico.

Herds can probably be improved in the safest way by the importation of bulls for crossing on native cows. There are a number of crossbred animals on the island that show improved formation and probably earlier maturity by reason of the cross.

PIGS AND POULTRY.

Improved breeds of pigs brought into the island have done well where they have received proper care. Disease is very rare among this class of live stock in Porto Rico. The method of handling these animals in the island is capable of much improvement. They are usually staked out near the dwelling of the owner and their feed is insufficient. Pigs more than any other class of domestic animals thrive best with a variety of food and especially require grass. With fenced lots and at large pigs will thrive much better than where confined with ropes.

The prices of poultry and eggs have been on the increase in Porto Rico during the past year. All classes of poultry stand in need of improvement by the importation of the better producing breeds. Poultry will thrive in all sections of the island with due care, but should be allowed freedom of range, should not be crowded, and should have some feed when grown in any numbers.

No serious epidemic diseases have been noted at the experiment station with chickens, ducks, geese, and turkeys. A disease producing lumps on the comb and at the base of the bill on chickens has been noticed. This seems to be a bacterial growth. Washing the heads of the fowls with a saturated solution of boracic acid gave relief.

REPORT OF THE PHYSIOLOGIST.

By OSCAR LOEW.

FERMENTATION OF TOBACCO.

Curing,^a as well as fermentation, is not so carefully conducted in Porto Rico as in the United States. The high temperature prevailing in Porto Rico, even until late in autumn, enhances, of course, the chemical changes characteristic of these operations. The fermentation in bulk is sometimes carried out in open houses without any steam jets and other contrivances found, for example, in the Florida fermenting houses. In one case observed in Mayaguez the temperature of the bulks reached only 44.5° C. when the bulks were repiled. In Florida, however, the bulks are taken apart and built up again when the temperature has reached 55° or 56° C., or about 132° F. This building up of the bulk is done five to six and even eight times. Thus the eggs of certain small beetles are killed before they can develop the insects which often damage the manufactured cigar.

There is no doubt that the so-called after-fermentation of tobacco proceeds much more energetically in the continuously warm climate of Porto Rico than in the United States. Hence, it seems unnecessary in case of the main fermentation to turn over the bulks of tobacco quite so often as in the States. The temperature of 55° or 56° C. should, however, be reached in each bulk the first time.

Mr. L. Du Bois, field manager of a large tobacco company, has carried on selection experiments with tobacco for several years. He mentioned to the writer the interesting fact that at one time a lot of tobacco selected from Porto Rico seed did not flower for two years and continued growth and development of leaves until a height of 14 feet was reached. The plants were afterwards lost by accident.

DISEASES OF TOBACCO.

As to diseases of tobacco, Mr. Harrison Johnson, a tobacco grower of Cáguas, stated that in his opinion the various troubles observed in the United States occur more or less in Porto Rico. The mosaic disease or calico, however, seems not to occur generally. Mr. Du Bois, of Cáguas, with many years of experience, also stated that mosaic disease was never observed on his plantation. But this disease has

^a The curing barns are usually exceedingly primitive huts.



FIG. 1. TOBACCO GROWING UNDER CHEESE-CLOTH SHADE NEAR CAYEY.

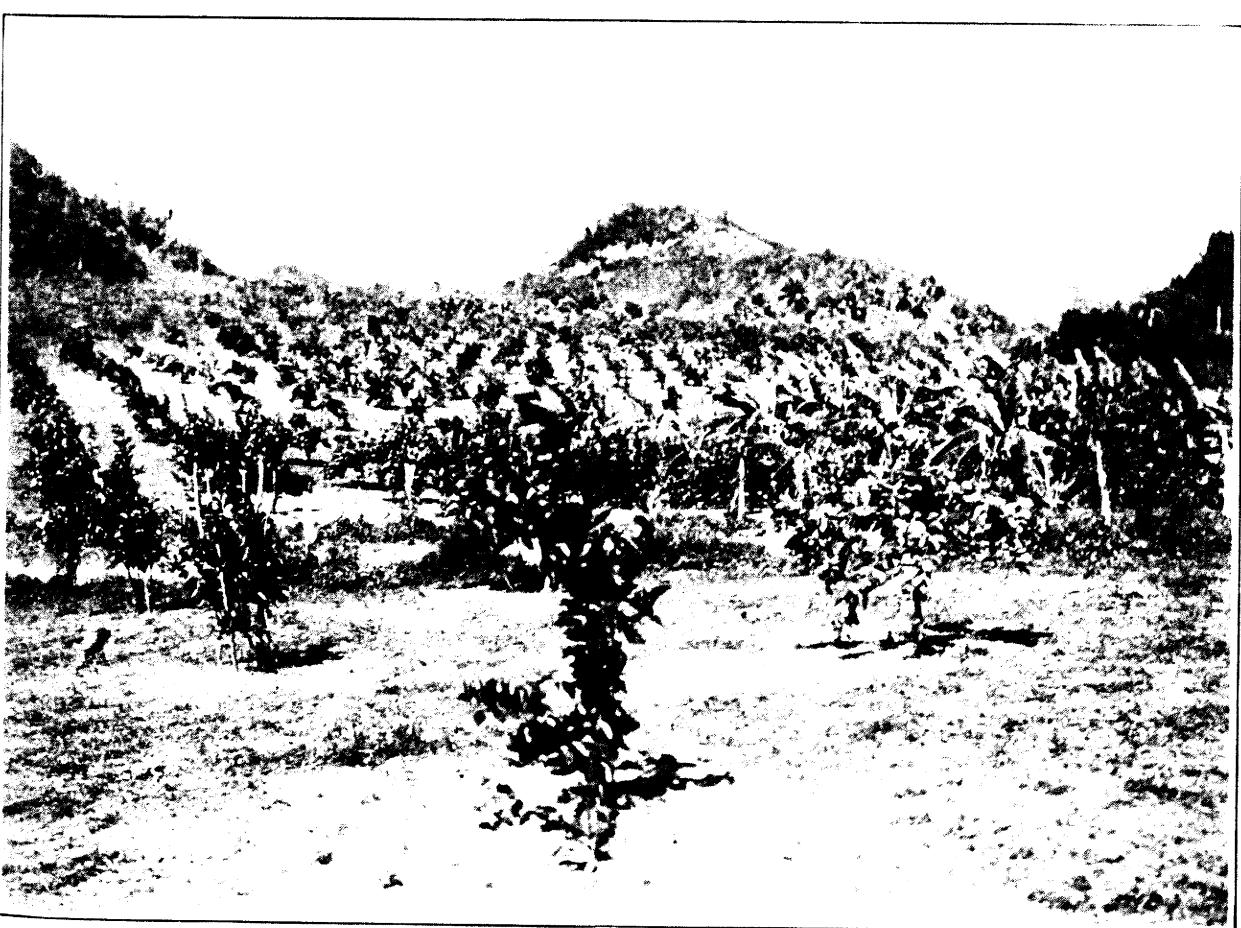


FIG. 2.—TYPICAL PORTO RICAN WIND-SWEPT ORANGE ORCHARD.

attacked tobacco plants near the experiment station. The wilt disease was observed only once, according to Mr. Du Bois. He also mentioned a trouble observed with the tobacco of a certain section of the Aibonito district. This tobacco, several weeks after its fermentation, acquires such a disagreeable odor that it becomes worthless. Some of this tobacco was procured through Mr. Frese, in charge of the tobacco depots in San Juan. The odor was moldy or musty, the veins were covered here and there with a white mass, and many of the stems were so rotten that they easily broke into fragments on being handled. The microscopical examination revealed no fungus mycelium, but numerous bacteria, especially cocci, as well as yeast-like cells, belonging probably to a kind of *Torula*. This disease resembles pole-burn. Various hypotheses as to the peculiar inclination of the tobacco of this district to the disease might be suggested, but without further examination it would be useless. Cotton-seed meal had been applied as fertilizer for a number of years on the affected fields.

A peculiar disease, spreading from a center in ring-like progression, was observed in the tobacco seed beds of Caguas. The circle of dead, bleached seedlings increased continuously and could be checked only by removing the soil to some depth and treating the spot with diluted formaldehyde (1 spoonful to 30 gallons of water). The disease is called "sancochado" in Porto Rico. On microscopical examination no mycelium of fungi was discovered, but numerous very lively nematodes were found which doubtless cause the disease.^a Mr. Du Bois has introduced a new system for avoiding the diseases of the seed bed, by transplanting the young seedlings into a second seed bed before they are set in the field. No top-dressing with nitrate is carried on.

The tobacco flea-beetle and the changa are considered the worst enemies of tobacco in Porto Rico. Most of the other insect pests of the field, especially the dangerous "cutworm," are avoided in growing the tobacco under cheese-cloth. (Pl. II, fig. 1.)

The tobacco of Porto Rico after fermenting is baled, and the numerous bales are then stored above and beside each other, resulting in a sort of after-fermentation in bulk. Since this may finally lead to loss of aroma by the fermentation going too far, the bales of tobacco are now also made up in some establishments in leaves of the royal palm (piraguas) instead of in the porous burlap, which admits too much air. The baled tobacco in a warehouse in San Juan showed last year much damage by mold fungi. It may also be mentioned

^a Mr. Tower, entomologist of the station, has also observed tobacco plants in full development near this station killed by nematodes. The roots showed many and irregular swellings.

that according to Mr. Du Bois the wrapper leaves grown under cheese-cloth when held toward the light often show green spots after the fermentation. This trouble will be examined as soon as occasion offers.

NOTES ON THE AVOCADO FRUIT.

The avocado or aguacate is the pear-shaped fruit of several kinds of *Persea*, a tree of Central and South America. This fruit, weighing from 300 to 400 grams, has a green to yellow skin, measures 10 to 11 centimeters in length, has a very large and globular kernel of 5.5 centimeters in diameter and a soft flesh of butter-like consistency surrounding the kernel to a thickness of 1.4 to 1.6 centimeters. The kernel, weighing from 90 to 95 grams, contains starch and oil, also some tannin; a freshly cut surface rapidly assumes a red color in contact with the air, probably on account of an oxidation of a peculiar compound. The seed is rather hard, but when boiled it softens and is then said to be readily eaten by hogs. The taste of the kernel resembles that of the horse chestnut. There is no flavor and hardly any taste to this part of the fruit.

The flesh shows on microscopical examination numerous oil droplets in the cells, while starch granules are absent, at least in the ripened state. Carbohydrates are represented by small amounts of cane sugar, invert sugar, and slimy substance. The oil obtained on extraction with ether proves to be of superior quality and might rival olive oil, should it be present in large amount and cheaply obtainable. Simple pressure would yield only a part of it, and this is rendered impracticable on account of the slimy substance present. Extraction with bisulphid of carbon might be too expensive in consideration of the rather low percentage, and a simple heating or frying process would impair the fine quality.

Many valuable data in regard to varieties of avocado, its culture, cost of production, etc., have been published by the U. S. Department of Agriculture.^a According to some chemical data published by the Department the flesh of the fruit contains 1 to 2.2 per cent protein and 10 to 17 per cent oil.

The fruit would no doubt find a market in the States if it would keep. Repeated shipments to New York have proved failures on account of decay of the fruits, believed to be caused by injuries to the skin, permitting the entrance of fungi. According to our own observations, however, every fruit, even with healthy uninjured skin and stem still attached, will gradually decay; that is, the skin will become brown and the flesh soft and sour. This process is analogous to the brown, mushy change often observed with certain varieties of pears. It commences at the core and proceeds outward until the entire fruit

^a U. S. Dept. Agr., Bureau of Plant Industry Bul. 77.

has softened and become brown. It is due to the dying off of the cells, caused either by insufficiency of oxygen or accumulation of carbon dioxid in the cells, whereupon some enzymes stored up in the protoplasm of the cells become liberated and act upon compounds dissolved in the cell sap. The dying off of the cells naturally causes the loss of turgor; consequently, a softening of the fruit is the concomitant of its death.

A special experiment was made in regard to this mushy change^a of the avocado fruit. Perfectly healthy fruits without any injury and with the stem still attached were selected and kept at 35° to 40° C. in a thermostat. After four days the skin commenced to turn brown, after two days more the fruit was soft and the skin had begun to shrink. Two days later the entire skin was deep brown and showed considerable and irregular shrinkage. On opening the fruit a brownish coloration, a peculiar, but not disagreeable odor, a sour reaction and taste, and some decrease of the slimy character of the flesh was noticed. Neither microbes nor mycelium were observable in the softened mass. Not even the most careful packing proposed will stop these changes, but cooling with ice will retard them.

^a This condition of pears is sometimes termed doughy; in German it is called "teigigwerden."

REPORT OF THE HORTICULTURIST.

By M. J. IORNS.

INTRODUCTION.

As noted in former reports most of the work in the horticultural department will require several years to obtain definite results. Such being the case, the work for the past year has been, in a large measure, a continuation of the work of the preceding year.

As preliminary to contemplated research work a careful study of the horticultural conditions of the island was necessary in order that the new work planned might be of practical benefit to the fruit growers as well as of scientific value. With this object in view, a number of trips were made to the various fruit-growing sections, many of the plantations visited and, as far as possible, the conditions and needs discussed with the fruit growers. Everywhere the greatest cordiality and cooperation was met with. As a result, several lines of work have been outlined, both for the station and for cooperating planters. Among the chief of these to be noted are the questions of cover crops, treatment of pineapple plantings after the second year, stock resistance to "mal de goma," effect of stock on scion, pruning, and plant selection, and breeding for special purposes.

One of the greatest difficulties to overcome is that of obtaining trained help. This is especially true when real scientific investigation is undertaken. The development of the fruit-growing industries has been so rapid that there has been no time to develop trained help sufficient to meet the needs. It is to be desired that native young men with good common school education take up this work and thus further the development of the fruit industries.

Another of the great needs of the island is more adequate inspection laws. Thousands of plants are being imported annually and practically nothing is being done to prevent the introduction of such destructive, if not totally annihilating, pests as the bud rot of the cocoanut, the mango weevil, and various other equally injurious insects and maladies. Thorough inspection laws, with adequate provisions for enforcement, would prevent the serious damage to the fruit industries of the island by the introduction of these pests.

The following is a more detailed statement of the work being done or planned in the various specific lines.

VEGETABLES.

The conditions in Porto Rico are apparently so nearly ideal for vegetable growing that one at once asks why the island does not supply its own markets and ship quantities of produce to the States instead of annually importing thousands of dollars worth of onions, potatoes, beans, and various other vegetables. Work of the preceding years at the station demonstrates clearly that the majority of vegetables can be raised here in abundance, but that seed deteriorates rapidly, necessitating frequent fresh supplies from the States. Can we raise our own seed as well as acclimatize the northern types and maintain the standard of such types, and also develop our own forms to that standard? We are now investigating these questions, with much promise of an affirmative reply.

It would seem also as though vegetables could be had fresh from the garden every day in the year, as frost is not known, and a temperature of 95° F. is considered hot. Even a wet and dry division of the year can hardly be said to exist in a large part of the island, and along the south and southeast coast, where there is a severe dry season, there is water for irrigation. The local markets indicate, however, that there is still present some of the old belief that certain vegetables will not grow on the island or can be grown only at certain times. To emphasize the former work of the station, a number of experiments are being carried on to determine more definitely just what the special seasons are, if there are any. To obtain this necessary data for each class of vegetable several varieties of what former experiments showed to be the best for this section were chosen. Plantings are being made at regular intervals of about a month. The plants are subjected to different cultural methods, such as growing in shade, ridge bedding, etc. Notes are taken of growth, yield, quality, and general behavior, together with climatic conditions. This work has not been carried on long enough to obtain many definite results, but the conclusions of former experiments are clearly confirmed, as well as some new points brought out and new questions raised. The chief of these are: That with proper cultural methods such vegetables as radishes and lettuce do equally well at all times of the year, unless it be during the one or two months of greatest rainfall; that many others do have certain seasons in which they grow best and, generally, that these seasons are during the early winter and spring months; that the insect pests and diseases are, in a large measure, periodic; that tomatoes, melons, cucumbers, and some others can be grown here for a winter or spring market; that good seed of many classes can be home grown and, most important of all, that the better native varieties can be readily improved.

When more frequent steamship service between Porto Rico and the States is established, as it soon must be at the present rate of develop-

ment of the fruit industries, an important market-gardening business will undoubtedly be developed, adding to the wealth and prosperity of the island. Even at the present time there is a good opening for such work for local markets, and a great improvement is seen in both quality and variety of the garden produce in the markets of the larger Porto Rican cities.

As will be noted in the report of the entomologist, excellent success has been had in combating the garden pests and diseases, so that that bar to successful trucking may be largely overcome. Some of the more stubborn diseases, like wilts and mildews, can be overcome by breeding and selection. Excellent success has been had along this line in grafting choice eggplants on the wild "*Berengena cimarrona*." The grafts seem proof against disease, and the fruits borne by them were large and of excellent quality. The plants also bore several successive crops, and would seemingly have continued fruiting indefinitely like the stock parent had not a newly appearing insect destroyed the plants before the pest could be checked. Other grafts are now coming into fruiting and it is hoped more definite results will be obtained by the time for the next report. The same stock is being used on which to graft tomatoes with considerable success.

Much remains to be done in the acclimatizing of the better northern types of vegetables and, by cooperative experiments with planters in other sections, attempts are being made to determine the best locations for such important crops as potatoes and onions, which require certain conditions for the best results. Many northern types and types from regions similar to our own should be introduced and the choicest native strains improved.

ORCHARDS.

Much of the orchard work thus far has been a continuation of that of the preceding years. Many of the introduced varieties of fruit trees are coming into bearing, and these are being studied as to their adaptability to our conditions and their commercial value. Among those that give promise of sufficient merit to warrant further investigations are the Japanese persimmon, the Peen-to peaches, the cherimoyer, the loquats, and several of the imported guavas.

Systems of pruning are being introduced; various cover crops are being tried; the fertilizing experiments continued and new ones planned to show the effects of the different food elements under Porto Rican conditions, and a comparative test of clean cultivation against grass in the orchard is being made.

A number of various types of citrus fruits are coming into bearing this year, making it possible to determine their merits as to shipping qualities and general commercial value. (Pl. II, fig. 2.) Some are found to be not true to name and in other cases, though labeled differently, varieties are found to be the same.

NEW PLANTINGS.

In order to study in more detail cultural methods, diseases, and various other problems of fruit growing several new plantings have been made. The chief of these are a new citrus grove and a cacao grove, with rubber for shade. Other miscellaneous plantings of cocoanuts, shrub forms, and various imported types have also been made. The new citrus orchard is located on tile-drained bottom land. The soil is a strong clay silt with some pockets of slightly sandy nature. This orchard, together with the old one, give us marked contrast of soil and soil conditions and permits of a large range of investigations. Only standard varieties of each class of citrus fruits are planted in this new orchard, and these are so arranged that experiments requiring many years can be carried on.

The cacao and rubber planting consists of five of the chief varieties of cacao in alternate rows of Castilloa rubber from Central American seed and from the seed of our own trees. A few quick-growing "Madre de Cacao" and rain trees are interspersed to act as shade during the first few years. This planting is made for the purpose of studying the cacao diseases, the best cultural methods, the use of rubber as shade, and some other problems.

MISCELLANEOUS FRUITS.

BARBADOS CHERRY (*Malpighia glabra*).—This fruit is proving of considerable merit for making jellies and has the advantage that it bears several crops each year. On the station grounds the trees thus far have borne one heavy and two light crops during the year.

OTAHEITE GOOSEBERRY (*Phyllanthus disticha*).—This fruit also has been shown to produce a very excellent deep wine-colored jelly and, like the Barbados cherry, produces abundant crops several times during the year, thus making a very valuable household tree.

ANONA (*Anona cherimolia*) has fruited during the year. While the fruits were small, they were all of most excellent quality. Other imported types are being planted, and it is hoped that this may become a common fruit in Porto Rico.

ROSE APPLE (*Eugenia jambos*).—A new use has been found for this fruit. When mixed with other fruits in making jelly or preserves it is found that it gives to the product a delicate rose flavor that is very agreeable. It would seem that this was well worthy of further trial.

GUAVAS.—The guava industry is one worthy of much attention and development. Since the pure-food laws prevent adulteration, pure jellies can be made profitably, as they will bring prices commensurate to their cost. Guava jelly is unquestionably one of the finest jellies on the market and the supply is almost nil compared to the demand. Hence the room for development is extremely large.

The guava is at home here, and there are many acres where it could be grown to advantage without interfering with other more profitable crops. It will grow in almost any situation, but responds readily to good treatment. The ideal conditions of soil, location, and culture are yet to be definitely determined. The introduced forms in the station orchard have thrived and this year bore excellent crops. Many hundred seeds have been gathered for sowing and for distribution. The mummy disease has not troubled the better imported types to an appreciable extent, and the native types have been kept nearly free by spraying (see report of entomologist, p. 38), so there is nothing to prevent the rapid development of this valuable industry.

AGUACATE.—The avocados on the station grounds have not shown satisfactory growth. This is probably due to unsuitability of location and climatic conditions. They have also been subjected to a leaf disease, the cause of which has not been fully determined, which has defoliated them.

CACAO.—Our cacao has done quite well during the past year. The growth has been vigorous, with a relatively small percentage of disease. Thorough pruning is being tried, as well as soil and cultural experiments. In connection with the physiological chemist, methods of fermentation and preparation of beans for market, as well as of improving their quality will be investigated during the coming year. With the entomologist and pathologist, studies will be made of the diseases and pests of the cacao and means of controlling them. These are now a bar to the industry, but it is believed that they may be overcome and cacao planting placed on a successful basis.

COOPERATIVE WORK.

Considerable data have been gathered in the cooperative experiments, some of which promise valuable results. It has been found that in all the soils thus far tried a complete fertilizer gives a marked increase in growth over no fertilizer or one composed of one or two elements only. This increase has in two cases been over 25 per cent where single elements were used, and more than 50 per cent greater than upon the nonfertilized plat. In no case has there been less than from 10 per cent to 15 per cent gain in favor of a complete fertilizer.

Thus far no injurious effects of using chlorids or organic fertilizers have been observed in citrus groves. The "mal de goma" present in some groves has not been traced to the presence of organic matter, but in almost all cases seems to be due to too deep planting, bad drainage, or some allied cause. In our orchard fresh manure has been liberally spread about the trees with beneficial results.

During the coming year it is hoped that data may be gathered on the effects of the various food elements on the fruit itself, as several of the experimental plats will bear their first crops. The fruits will be

analyzed and compared for quality and shipping purposes. These experiments will be continued until definite results may be had on all of the questions raised.

COCOANUTS.

The past year has been very profitable for cocoanut growers; prices have been high and the crop fair. In favorable localities the crop has been very large. The high prices and the bearing records of the Porto Rican trees have given a great impetus to cocoanut growing and a number of large groves are being set out. There is also much general planting being done.

Efforts have been made to obtain some data regarding the number of fruits a tree will bear during the year. Though many countings have been made, the variation has been found to be so great that as yet it is impossible to give any accurate figures. Trees have been observed with as high as 225 nuts on at one time, and the bearing of from 125 to 150 nuts at one time has been found very common in the section where the cocoanuts are most at home. Most authors reporting on this subject give an average of 120 to 125 nuts for the whole year, but from data gathered here it would seem as though there is a higher average in the better cocoanut sections of Porto Rico.

Cultivation, fertilization, and seed selection are found to have an important influence on the rapidity of the grove's development as well as its productiveness. From data obtained it can be strongly recommended to those starting new groves that they look carefully to the physical condition of their soil, the selection of their seed, and the cultivation and fertilization of the trees. By thus doing they may gain from one to three years in the development of their groves.

Thus far none of the dreaded cocoanut diseases have been observed or reported. There are some minor diseases present in the groves, but they are almost entirely due to neglect of the trees and are not to be feared by the careful grower.

RUBBER.

Several of the Castilloa trees on the station grounds have flowered and fruited during the year. Many thousand seeds were gathered, most of which were distributed. It was determined that when the seeds were planted as soon as removed from their seed pods 97 to 98 per cent germinated. When left to dry out, the time of germination was lengthened and the percentage of those germinating decreased. Seeds allowed to dry for three weeks required as much as five weeks to germinate as opposed to five to eight days when fresh. The seedlings were found to stand transplanting very well. Some were transplanted twice, from seed boxes to pots and from the pots to

their place in the orchard, with but an exceedingly small percentage of loss—no more than is to be expected with any of the common tree types. How old the seedlings can be before they are stunted by transplanting is a question yet to be determined.

It is hoped that some tapping may be begun during the year, although the trees are less than 6 years old and too young for more than very light experimental work.

MANGOES.

The interest in mango growing is increasing. The mango tree makes in many ways the ideal permanent wind-break, so vitally essential to our citrus groves. Thousands of seeds are being planted and the demand for the better imported forms is rapidly increasing.

During the past year nearly 200 inarches have been made from the various imported forms and most of these are being planted on the station ground where wind-breaks are needed. Some have been distributed and others will be as fast as it is deemed advisable. Various methods of grafting, budding, and inarching are being given trial with more or less promising results. It is our desire to find if possible some rapid, simple way by which the seedlings may be grafted or budded in situ with more certainty of success than by any of the methods thus far used. Such a method will do away with much of the present necessary labor and danger of loss and will give an impetus to what should be a prominent industry on the island.

Shipping trials of mangoes were made during the season to further determine the best methods of packing, handling, etc., and the carrying qualities of the fruit. These experiments were successful as far as keeping qualities are concerned, and it seems only a matter of time until the mango will become a valuable factor in our export trade.

It was found that the best time to pick the fruit for shipping was when it began to show the faintest color of approaching maturity. Fruit picked at this stage arrived at its destination in excellent condition and developed a flavor and quality approaching that found in the fruit ripened on the tree.

Experiments were also made with the mango fruit for other purposes. At certain stages of maturity the fruit was found to make excellent jellies, butters, and sauces, and it is probable that it may be canned. More work is to be done along these lines in the coming year.

BANANAS.

The banana plantation is showing excellent growth and a number of the new varieties are now fruiting. These new types are being described and tested for their economic value. A number of forms secured from different sections, but bearing different names, are found

to be the same, thus reducing the number of varieties in the trial grounds. Forms that have no merit are discarded.

The chief and vital objection to the growing of bananas for export has been the fact that the bunches were too small. In Porto Rico a bunch with six or eight full hands is considered large. Whether this characteristic of small bunches is due to the variety, soil or cultural methods is yet to be determined. The quality of the fruit is excellent and the number of bunches produced on a given acreage is fairly large, so that if the size of the bunch could be increased or more prolific varieties grown bananas could well be raised for export.

PINEAPPLES.

The pineapple industry has developed with exceeding rapidity and has become one of the chief industries of the island. The new acreage planted during the year was limited only by the available supply of slips. Not only were all the local supplies exhausted, but hundreds of thousands were imported from Cuba, Florida, and other pineapple-growing sections, and even then the demand was not met. This extensive planting may lead to great injury, as in many cases inferior slips were secured and the lack of inspection gave opportunity for the introduction of any and every form of disease and insect. Aside from the troubles arising from the planting of inferior slips no new disease or insect has been reported or observed. Growers should watch their plantings with great care and report any new trouble immediately, so that means may be taken to prevent the spread of any dangerous diseases.

The fertilization experiments that have been carried on for several years have been concluded and this information, together with much other data, is being prepared for publication. Observations made in the field have led to the undertaking of considerable other work with pineapples. It is necessary to more clearly determine the best methods for bedding, the treatment of the different soils, and proper soil conditions. Also considerable work is to be done along the line of plant selection and improvement. In several regions Red Spanish plants were observed that were practically spineless. Effort will be made to develop this characteristic. Several promising variations in type will be propagated and fixed, if possible.

During the past year pineapple shipments have been very satisfactory, both in carrying qualities of fruit and prices obtained. The new crate for the Cabezona pine, designed by the former horticulturist, Mr. Henricksen, has demonstrated its usefulness, and many thousand crates of this pine were put on the New York market in excellent condition. Should shipping become unprofitable because of low prices the planter has yet another resource, for new canning factories have been started at Mayaguez and San Juan, thus giving a larger home market.

Steps should be taken toward the adoption of uniform standards as to grading for quality, and more particularly for size. At present these standards are very indefinite, being almost entirely dependent upon the individual. Some size by weight, but most by the eye, and for the average man this is not accurate. Unless some means are taken to make the packages more uniform injury to the industry will result. These are proper questions for fruit associations to take up, and their committees should meet and formulate standards for use by all their members. The merits of a system of sizing by weight as practiced by some should be thoroughly discussed. If the crown of the pine did not vary so much weight would unquestionably be the ideal system to insure uniformity; but because of these extreme crown variations some modifications will be necessary.

The new varieties in the experimental beds on the station grounds have not done as they should, due to the extremely unfavorable conditions of most of the past year, and it is impossible to make any fair report of them at this time.

PLANT INTRODUCTION AND BREEDING.

As noted under their respective heads, new varieties of citrus fruits, pineapples, etc., have been introduced and distributed or planted in the experimental beds for trial or propagation. Some of the other special work done along these lines is as follows:

A large number of the standard varieties of grapes have been introduced and planted. They have made an exceptional growth during the year, and it has been found difficult to keep them within bounds. It has been observed that while in full growth heavy pruning can be done without seeming injury. Pruning when the vines were semi-dormant caused severe bleeding, which was checked only by cauterizing and then covering with wax. The best method is, of course, careful watching and pinching the buds before the growth fairly begins. By one or two heavy prunings at the proper time and pinching it is possible to keep the vines in good bearing condition.

The introduction of nut trees will be given considerable attention during the coming year. In many localities the conditions seem to warrant the belief that English walnuts, almonds, pecans, and other forms like Brazil nuts, litchi nuts, etc., can be raised here, and it is desired to take up the matter of their introduction, seeking the best localities and soil conditions for each form. Could these forms be used to reforest our hills and our waste places as well as be grown in groves it would add very materially to the wealth of the island.

Many new varieties of strawberries are being tested in the experimental plats. Some of these varieties have stood the adverse conditions of drought and excessive rains and are giving promise of producing excellent fruit. Others are yet too young to pass an opinion

upon. There has been enough work done in several places on the island to show that strawberries can be successfully grown. While the crop is not heavy at any one time as in the States, the bearing period lasts over several months, so that the total yield is very fair.

PLANT IMPROVEMENT.

In plant improvement special emphasis is being laid on the breeding for disease resistance in various varieties of plants. The tomato, eggplant, cucumber, and muskmelon are being given special attention. As stated previously, grafting tomato and eggplant on the wild eggplant has been very successful, and we are also trying by cross-breeding with the hardy native forms and by selection from the resulting hybrids to breed new, hardy types of high quality.

Most excellent success has been already obtained with muskmelons. A native strain of large size has been found with merit enough to warrant further work. By using fertilizers these have been grown to giant size while still retaining an excellent flavor. Another type locally known as the "melón de la China" has proven to be of exceptional merit for a breakfast or dessert melon, ranking well with the Rockyford in size and flavor and excelling it in appearance, being of a fine orange color when ripe. This melon is being tested for shipping, improvement of size, productivity, and flavor. Much is expected of this strain, both for home and foreign markets. A famous strain of Spanish muskmelon is also being tested.

Another line of work being pushed is onion growing. It is claimed by the dealers, and seemingly well substantiated, that the onions grown in the United States and even the Bermudas do not keep as well as the Spanish onions. Spanish onions have been planted and will be grown for seed. Efforts will also be made to obtain seed direct from Spain for trial here. There is no apparent reason why our large home demand can not be supplied and that large, important item of expenditure kept at home to add to the island's wealth. The success of the onion plats so far developed on the station grounds bear out the above conclusion.

Efforts are being made to adapt and grow the garbanzos, or chick peas, a Spanish vegetable that serves almost the same purpose as beans and is at present a large item of importation.

By selection an extra fine as well as extra early strain of cowpeas has been developed and now we are raising seed for trial at other points on the island.

Cowpeas promise much for Porto Rico, and any improvement will mean great benefit to the planters. The breeding crops thus far have matured in from sixty-three to sixty-eight days, and with favorable conditions it is probable that this time can be considerably reduced.

Practically all of the standard vegetables are under observation for adaptation and improvement and all the native strains that give any promise of merit are being tested.

FRUIT GROWERS' ASSOCIATIONS.

One of the encouraging signs in the growth of the fruit industries is the awakening of the planters to the value of cooperation. During the past year the two old associations have made a vigorous growth and one new association has been formed among the fruit growers around Manati. There is nothing that can build up an industry so rapidly and substantially as active, thorough cooperation, and fruit growing is especially susceptible to such efforts, as evidenced by the development of this industry in Oregon, California, Canada, and various other sections.

These associations are taking up the question of shipping rates and facilities and various other matters of importance in their lines of work. Unquestionably they can accomplish much good both for themselves and for the whole island. It is to be hoped that other associations will be formed in the various fruit-growing centers and then that all these local associations form a strong, vigorous federation. By such steps they can soon control the situation and bring about many needed shipping reforms.

REPORT OF THE ENTOMOLOGIST AND PLANT PATHOLOGIST.

By W. V. TOWER.

No serious outbreaks have been reported during the last year, although there are a number of pests which are giving the planters a good deal of trouble. Several trips have been made through the orange and pineapple districts, and there seems to be a marked improvement in the groves. A number of beneficial parasites have been bred and their life histories are being worked out. These insects are to be bred and distributed during the coming season. Tobacco insects are causing the planters considerable trouble, and during the coming year cooperative work is to be carried on. Since March a great deal of time has been spent in studying the life histories of the insects affecting vegetables; also various methods for combating them.

ORANGE PESTS.

The "orange dog," a variegated caterpillar belonging to the genus *Papilio*, was found feeding on the orange during July. Some of these caterpillars were bred and pupated during August. The rest of the insects were fed on orange leaves sprayed with arsenate of lead, 4 pounds of stock to 50 gallons of water. This strength was effective. A second brood was observed October 18. The larvæ at this time were half-grown.

The orange leaf-weevil (*Diaprepes spengleri*) was found in limited numbers during the past season, but in the latter part of May great numbers were observed. At this time arsenate of lead, 3 pounds to 50 gallons of water, was sprayed on a number of trees, which were then tented, inclosing the weevils. In three days 75 per cent of the weevils under the tent were dead.

On one trip through the orange district there was found a very high percentage of scabby fruit. From the work carried on at the station it seems advisable for this trouble to spray just as the fruit forms, also again in ten to fourteen days. Trees treated with Bordeaux mixture showed a very low percentage of scabby fruit. It is advisable to have the scale well under control before spraying with Bordeaux mixture, as it kills the parasitic fungi which prey upon the purple scale.

As means of prevention: (1) It is not advisable to plant nurseries of rough lemon between budded rows of trees, as it is very suscepti-

ble to scab. (2) Do not plant nurseries on the windward side of groves, as the wind acts as an agent for distributing the spores of the fungus which produces scab. As scab and the orange weevil appear about the same time, it is recommended that a fungicide and insecticide be applied together. This can readily be done by dissolving 4 pounds of arsenate of lead in 50 gallons of Bordeaux mixture.

The red scale (*Chrysomphalus ficus*) is as pernicious as the purple scale, but there seems to be a definite time when the young come forth. The young settle down in about two days, forming their first covering. This first covering appears yellow, but it is transparent, the yellow of the insect shining through. The second covering is somewhat darker. These two stages are readily killed with kerosene emulsion, 1 part of stock to 6 parts of water. As the young are not all brought forth at the same time more than one spraying is necessary. For treatment spray when the crawling young first appear and repeat in three weeks. If the insect is very bad another spraying will be needed.

"Cuculios" or May beetles (*Lachnosterna* spp.) were reported in some of the groves this year at blossoming, while in some sections a number of planters observed the "cuculios" eating the young fruit, thus scarring it. If this is the case thorough spraying should be practiced before the fruit forms. It seems advisable, when there is a great amount of scab in the groves, to apply both a fungicide and insecticide—4 pounds of arsenate of lead to 50 gallons of Bordeaux mixture.

The brown or hemispherical scale (*Saissetia hemisphaerica*) is not causing any serious trouble at present. It is readily held in check with 1 part of stock kerosene emulsion to 6 parts of water.

The purple scale (*Lepidosaphes beckii*) is causing a great deal of trouble in the citrus plantations. This insect has been under close observation for the past year at the station, and a number of planters have upon request sent specimens for study. From the observations made it was found that the young are frequently issuing. Experiments have been carried on to determine the value of the different strengths of sprays and at what stages the purple scale are killed by these insecticides. The adult females and eggs are very hard to kill, and a spray which would kill at these stages would cause many leaves to drop. Crawling young and young bearing their first covering are killed by much weaker solutions. Kerosene emulsion, 1 part of stock to 6 parts of water, kills larvæ with their first and second coverings. The complete history of this insect has not been worked out, and until this is completed it will be impossible to say just how many sprayings will be necessary to clean a grove.



FIG. 1.—TEMPORARY WIND-BREAK OF BANANAS.



FIG. 2.—PERMANENT WIND-BREAK OF MANGO TREES.

WIND-BREAKS.

Wind-breaks are now recognized as playing as important a part as sprays in checking the purple scale. During the past season many of the planters have been setting out groves with wind-breaks, and under such conditions parasitic fungi are developing.

Wind-breaks are divided into two classes—permanent and temporary. Permanent wind-breaks are generally planted on the outer borders of the groves, while temporary wind-breaks are planted between the rows of trees. There are several plants which grow very quickly and afford good wind protection, namely: Bananas, sugar cane, pigeon peas, and the China berry. Temporary wind-breaks (Pl. III, fig. 1) should not remain between the rows more than three years, and in the case of bananas a furrow should be plowed on each side, thus preventing the roots from sapping the soil around the orange trees.

For permanent wind-breaks at the present time the mango seems to be the best (Pl. III, fig. 2), but in setting out the young trees they should be headed as low as possible. Bamboo is also being planted, and if the cuttings are set out during the rainy season they start much quicker. These should be planted close together, so as to form a hedge.

When brush land is being cleared for planting it is advisable to leave a strip of uncut timber 20 feet wide every 300 to 400 feet. The results obtained from wind-breaks are very marked, certain groves which were wind swept and were not growing at all having been brought into excellent condition. In almost every grove on the island marked improvements by wind-breaks have been observed. In certain areas there may be found trees producing from one to two boxes of fruit, while trees not more than 50 to 70 feet away and of the same age as the former, but without wind protection, appear to be not more than a year old. On the latter the branches are blown to one side and covered with scale. Trees protected from the wind require less spraying and the fruit is free from scars.

The rust mite has been found in some of the groves during the past season, but very little damage has been noted. During the coming season various sulphur washes are to be tried in cooperation with the planters as measures against the rust mite.

KEROSENE EMULSION.

Kerosene emulsion made according to the usual formula has given excellent results at the station and also on many of the plantations: Take 2 gallons of kerosene, 1 gallon of water, $\frac{1}{2}$ pound of whale-oil soap. First put the oil in a barrel. Then dissolve the soap in the

water by boiling and pour into the barrel. Mix the whole with a spray pump by pumping back into the barrel for ten minutes. A creamy mixture will be obtained which should hold up for from two to three weeks. For use follow directions given for the different insects.

TOBACCO INSECTS.

There are a number of insects which feed upon tobacco and which for convenience may be divided into two classes—those that damage the young plants in seed beds and those that damage the leaf in the field.

In making new seed beds it is a good practice to burn brush over the beds or to sterilize the soil by steam, thus killing all insects which may be present. Seed beds covered with a thin layer of powdered charcoal have been used at the station for preventing damping off and other similar diseases.

INSECTS WHICH INFEST SEED BEDS.

Young tobacco plants are killed by cutworms and "changas" and seriously damaged by flea-beetles and hornworms.

The "changas" and cutworms eat the plants when they are 2 or 3 inches high. The "changas" cut off the plants below the surface of the ground, while the cutworms cut the plants just above the soil. Paris green mash has been used at the station with excellent results. In using this poison it is advisable to make small cones, placing part of the mixture below the ground and part above. The mash under ground is for the "changas," while that above the surface is for the cutworms. This mixture is also very useful in vegetable seed beds, and in transplanting vegetables and tobacco a cone should be placed near each plant. The station recommends the following formula for Paris green mash: Twenty pounds of bran or corn meal, $\frac{1}{2}$ pound of Paris green, 1 gallon of molasses, and $1\frac{1}{2}$ gallons of water. Sprinkle the Paris green over the meal and thoroughly mix the two, then add the water and molasses, making a thick paste which can be molded into small cones.

Flea-beetles and hornworms do a great deal of damage to young plants. They may be controlled by spraying with 3 pounds of arsenate of lead to 50 gallons of water.

INSECTS FEEDING ON LEAF TOBACCO.

Flea-beetles and the hornworms are the most serious insects infesting tobacco. For these two insects 3 pounds of arsenate of lead to 50 gallons of water are recommended. No burning has been observed in using this insecticide.

Hornworms are causing much damage in the Caguas and Cayey sections. The eggs and larvae are gathered by women and boys. In July a parasite was found depositing its eggs in the egg of the hornworm. Notes were taken on the insect and as many as eight parasites have been secured from one egg of the hornworm. A great number of eggs of the hornworm were gathered and the life history of this insect was studied. From observations made it was found that the parasite takes about eleven days to develop. The adults mate very soon after issuing, and the females after depositing their eggs die in a short time. These parasites were determined by Dr. L. O. Howard as *Telenomus monilicornis*.

Nematodes have been found infesting seed beds. For their destruction soak the infested areas with a formalin solution, 1 tablespoonful of formalin to 1 gallon of water. This has given excellent results in beds where the plants are an inch high. A strong solution of mustard or tobacco water may also be used.

INSECTS AND DISEASES OF VEGETABLES.

During the spring and summer months cooperative work in spraying garden truck was carried on with the horticulturist. A number of interesting pests appeared, various sprays were tried, and those used on the insects were more successful than those used for the plant diseases. Bordeaux mixture and arsenate of lead were used together with excellent results. It was found that during the dry season all vegetables were comparatively free from disease, while those that were infested readily responded to treatment. This can also be said of the diseases found during the summer or wet season, except that the number of applications had to be increased, thus increasing the cost of production. *Plutella maculipennis* appeared the first part of the season and did considerable damage to cabbage, kale, mustard, and turnips. The larva is a very small green caterpillar three-eighths of an inch in length. It was found feeding on the under and upper surfaces of the cabbage leaves. The pupa case is generally made on the underside of the leaves, but occasionally it was found on the upper surface. Paris green and slaked lime, arsenate of lead, and kerosene emulsion were used, but as the cabbage leaves are very glossy the spray did not adhere. In May a parasite was found which deposits its eggs in the pupae. A number of these insects were raised and set free. At the present date it is impossible to find any of the work of the caterpillars. Arsenate of lead was very effective as a spray for checking these insects on the mustard and turnip. Kerosene emulsion, 1 to 8, killed a large percentage of the larvæ, but it was not as effective as the parasites.

There have been two broods of the southern cabbage worm under observation, and a number of notes have been taken concerning its

life history. The females deposit their eggs in clusters on the under side of the leaves, the number of eggs ranging from 13 to 105, with an average of 45. The complete life history covers from 24 to 26 days. The egg clusters are readily seen on account of their yellow tint. These must not be mistaken for the eggs of the ladybug, which feeds on the larvae of plant lice. The eggs of the cabbage worm are ridged, while those of the ladybug are smooth. Among the insecticides used arsenate of lead, 3 pounds to 50 gallons of water, was the most effective. Paris green 1 part and slaked lime 25 parts was also effective. This mixture should be dusted on the plants in the morning while the dew is on. Other food plants of the cabbage worm are radishes, turnips, kale, and mustard.

Tobacco hornworm eggs were found on tomatoes and pepper, but the larvae were held in check by the egg parasite *Telenomus moniliicornis*.

A white fly (*Aleyrodes* sp.) appeared in great numbers on the pepper and tomatoes, but no serious damage was noted. There appears to be a great number of parasites which should be encouraged. Two species of syrphid flies were bred, and part of their life history worked out. A parasitic fungus was also found on the white fly, and at the present time it is checking the ravages of this insect.

Plant lice (Aphididae) were found on many of the vegetables, especially on the first two plantings. A number of parasites were found, two species of ladybugs were bred, and one species of syrphus fly, and a hymenopterous parasite was discovered laying its eggs in the pupae. Tobacco water and kerosene emulsion were used during the first part of the season with excellent results, but at the present date parasites are playing a very important part holding the Aphididae in check. Other food plants of Aphididae are cabbage, turnips, mustard, melons, cucumbers, tomatoes, and squashes.

The striped cucumber beetle (*Diabrotica vittata*) was found feeding on the cucumber, squash, and melon, also on some of the native weeds. To combat them clean out all the weeds which act as food plants and then spray with arsenate of lead, 3 pounds to 50 gallons of water. It is advisable to spray with a mixture of Bordeaux mixture and arsenate of lead, as the Bordeaux mixture protects against the mildews and other diseases and the arsenate of lead against the insects.

SUGAR-CANE INSECTS.

Mealy bugs have been causing some trouble to the planters on the eastern end of the island. This pest seems to be spread by planting "seed" which has been taken from infested areas. A number of experiments were carried on at the station with kerosene emulsion, using it as a dip for infested canes. From figures obtained from these experiments it was found that with seed soaked for ten minutes in

kerosene emulsion, 1 part of stock to 6 parts of water (see p. 33), all insects were killed and 95 per cent of the canes germinated.

Specimens of sugar cane infested with the melanconium stage of *Tricosphaera sacchari* were collected from a number of plantations. An outbreak of this disease occurred on the south side of the island in a very limited area. This area is being treated.

For preventing this disease ratooning should not be practiced on infested areas. New plantings should be made with selected seeds which have been treated with Bordeaux mixture. After cutting the cane on all infested areas the infested stalks should be gathered and burned. Areas seriously infested should be burned as soon as the cane has been removed.

The sugar-cane weevil (*Sphenophorus* sp.) was found during December, January, and February in canes which were being cut for grinding. Borers were found in stalks, making large cavities between the nodes, and larvae ranging from three-eighths inch to 1½ inches long, pupæ, and adults were found in the same canals; eggs have not been observed.

The larva is a white, footless grub. The anterior portion of the head black, while the posterior portion is brownish red; mandibles black; anterior portion of first segment of body reddish brown. On segments 4 to 7 there is a swollen area or hump which assists the larva in locomotion. Anal segment bears 4 pairs of reddish-brown hairs. The adult is reddish with black markings. Head black; beak brownish red. Canes eaten by this borer become weakened and fall over, thus making a place for infection, and finally the whole stalk becomes infested with fungi. The treatment recommended is to collect and burn all infested canes at time of cutting.

A very small borer belonging to the genus *Xyleborus* was found infesting healthy canes. Upon examination all stages of this insect were found. The life of this insect is passed in sugar cane, males and females coming forth to mate. From the appearance of the canes the borers come forth from the nodes and in these canals fungi are found. The same treatment as for the weevil is advised.

The rice weevil (*Calandra oryza*) was found in very limited numbers. At present it is not causing any trouble.

PINEAPPLE INSECTS.

Pineapples during the past year have been comparatively free from diseases and insects. However, a few diseased plants have been reported in the San Juan section. A bacterial disease has been reported in Florida, and as many of the slips coming to the island are from Florida we may expect this disease.

Mealy bugs at present are causing a great deal of trouble. Young plants have been found infested, the trouble being traced to the parent plant. These infested slips should be dipped in kerosene

emulsion, 1 part of stock to 9 parts of water, for from five to ten minutes. Whole sacks or boxes of slips can be dipped at once, but these plants must not be left in the sacks or boxes for more than five to ten hours, as they will be liable to heat. When infested plants are set out in the field, ants distribute the young mealy bugs over the new growth, even to the base of the fruit. Insects were found in great numbers in the spaces between the calyx tubes, while on the outer edges of these cavities there appeared a secretion of gum which was probably caused by the mealy bug breaking down the cell structure. These areas were found on the green fruit, but upon microscopic examination no fungi were found. A number of these fruits were allowed to ripen, and the infested areas ripened first. A great number of immature mealy bugs were found in the closed calyx tubes, but it seems probable that the eggs were laid by the female before the calyx closed over.

Tobacco dust placed in the crown of the pineapple has given excellent results in checking the mealy bug. The rains and the dews collect in the crowns and dissolve the tobacco dust, thus making a strong extract, which slowly passes down over the base of the leaves and finally around the roots. Cotton-seed meal is used by many of the planters as a starting fertilizer for slips. In such cases it is recommended that the tobacco dust be mixed with the meal.

MISCELLANEOUS NOTES.

Icerya montserratensis was sent to the station for determination, having appeared on the orange. Kerosene emulsion, 1 part of stock to 6 parts of water, was recommended, and under this treatment the infested areas were cleaned.

Pulvinaria psidii was found on the orange and coffee.

Specimens of rufous scale (*Selenaspisidus articulatus*) were sent to Mayaguez on the orange, and later it was found on the rough lemon. This scale appeared on the leaves, which were infested with purple scale, but the black fungus which was preying on the purple scale did not work on the rufous scale.

The wax scale (*Ceroplastes floridensis*) has been found during the past season on the rose and orange.

Mummy disease of guavas was reported in the last annual report as appearing on the imported Florida guavas. Last season the infection was about 40 per cent of the crop. The 1907 crop was sprayed with Bordeaux mixture a number of times and the mummied fruit was reduced to 10 per cent. These experiments are to be continued for a number of seasons to determine the proper time of spraying and the number of applications necessary to produce clean fruit.

The following mosquitoes were collected at Mayaguez, Porto Rico: *Aedes mediovittata*, *Culex bisulcatus*, *Culex pipiens*, *Culex cubensis*, *Culex salinarius*, *Culex toweri*, and *Stegomia calopus*.

REPORT OF THE COFFEE EXPERT.

By J. W. VAN LEENHOFF.

The abundant blossoming of May, 1906, accompanied by excellent weather conditions, resulted in a large coffee crop. Storms lasting continuously from November 25 to December 14, 1906, and again from March 26 to March 28, 1907, did much damage to old and young trees, especially in less protected places. The young coffee was on different occasions thrown flat on the ground stripped of leaves, and had to be straightened and many trees sustained with forked sticks. Through the strong shaking by the wind, holes were formed in the soil around the trunks, which were carefully filled in with earth. The greater part of the trees recovered rapidly.

The results of these storms show the necessity of many more wind-breaks. As provisional protection plantains were planted between the rows, to be removed as soon as the shade had grown to a sufficient height. This is exactly what Porto Rican planters have done and, although their claim that young coffee wants heavy shade has not been proven, it seems that a statement that young coffee in Porto Rico requires many shade trees for wind-breaks would not be far from the truth.

IMPROVEMENT OF AN OLD COFFEE GROVE.

Experiments were continued and yields determined on different tracts of old coffee. These experiments are for the purpose of studying methods of bringing old coffee plantings up to a higher state of productivity. The crop from 10 acres in 1902 was 3,387 pounds. The plat was then divided into ten 1-acre plats, and on each a different method of treatment was followed. Altogether 1,106 trees were removed and others trimmed up. The yields since have been as follows:

Yields from a renovated coffee grove.

	Pounds.
1903	1,623
1904	1,184
1905	2,339
1906	4,349

The indications are that yields will increase for some years. Full details of the experiments will be made later in bulletin form.

Scarcity of labor, caused principally by the enormous demand in the tobacco industry, increased the price of picking 12½ per cent last year.

Cost of gathering and preparing 100 pounds of coffee for market.

Cost of picking	\$1.56
Cost of field labor	1.45
Preparation for market	.75
Transportation from field	.20
Transportation from plantation to Ponce	.37½
Total	4.33½
Average price obtained per 100 pounds	10.88½

The following estimates are given of the cost of the new plantings of coffee:

Expenses per acre for 1907:

Five weedings, at \$1.33½	\$6.67
Repairing damage after storm, estimated	3.00
One hoeing between rows	4.44
Expenses, third year	14.11
Expenses, first and second years	75.88
Total, three years	89.99

There was gathered the third year:

80 pounds of coffee, worth \$10.65 per 100 pounds	\$8.52
Less picking, preparing, and transporting	2.23
	6.29
Net cost per acre to the end of third year	83.70

DISEASES AND INSECT PESTS.

All the diseases and insect pests mentioned in previous reports have continued to do more or less damage. The experiments in fertilizing to overcome the losses due to the leaf-miner (*Leucoptera coffeella*) seem to give good results, the field described in former report having not only completely recovered but showing very vigorous growth, with a very noticeable decrease of the brown spots on the leaves.

A new insect was observed in old coffee near Juana Diaz. A number of the trees were found to be attacked by a borer, which eats its way in a vertical direction through the heart of the trunks and branches. This pest is now under investigation.

EXPERIMENTS WITH NEW PLANTINGS.

The foreign coffees have been increased by the addition of some other of the best Javas, sent by the gardens at Buitenzorg, and by Blue Mountain coffee from Jamaica. During the coming year a number of introduced coffees grown on the experimental grounds will be submitted to experts for a determination of flavor.

THE FERMENTATION OF CACAO AND OF COFFEE.

By OSCAR LOEW, *Physiologist.*

THE FERMENTATION OF CACAO.

Although much has been written about the fermentation of cacao, there still exists a great difference of opinion in regard to the process, its purpose and necessity, and the kind of action involved in it.

Herbert Wright, in his exhaustive work on cacao^a, mentions yeast cells^b as the most important organisms causing the fermentation, while other authors attribute the fermentation to unorganized ferments, others again to bacteria, and even the changes due to germination were supposed to play a rôle in it.

According to George Watt, in his Dictionary of the Economic Products of India^c—

The coolie dexterously strips all the beans off the center pulp. The pods are then thrown round the trees and act as manure, while the beans are removed to the fermenting cistern. It takes from five to nine days to properly ferment the cacao and it is then ready for working. It is trampled first, as in coffee, with the feet and then removed in baskets and carefully hand-washed.^d
* * * I have no doubt that before long some means less expensive will be found for washing. * * * The prices obtained for it will depend in the much greater measure on the careful attention of the curing than in the case of coffee.

Safford, writing on cacao in Guam,^e says:

Cacao beans are sometimes kept in jars and allowed to "sweat" or undergo a sort of fermentation which improves their flavor, but this custom is not universal. Many families, after having dried the beans in the sun, keep them until required for use, when they toast them as we do coffee, grind them and make them into chocolate. Chocolate made from the newly ground bean is especially rich and aromatic.

Hinchley Hart^f writes:

The prime object of sweating or fermentation appears to be to change the inside portion of the bean by absorbing into it products obtained from the fermenting pulp, and where this is not fully accomplished by any of the methods the bean is classed as unfermented, and the product is generally of lower value.

^a *Theobroma cacao* or *Cocoa*. Colombo, 1907, p. 108.

^b According to A. Preyer (*Tropenpflanzer*, 5 (1901), pp. 157-173), a special kind of yeast, which he named *Saccharomyces theobromae*, effects the best fermentation in Ceylon.

^c London, 1893, vol. 6, pt. 4, p. 44.

^d Such methods are followed in India, but not in America.

^e Useful Plants of Guam. U. S. Nat. Mus., Contrib. Nat. Herbarium, 9 (1905), p. 387.

^f Cacao. Trinidad, 1900, 2. ed., p. 38.

The changes brought about by the fermentation have been minutely examined by J. B. Harrison, chemist in British Guiana. Some of the changes observed, as, for example, the decrease of protein in the seed and the increase of amido compounds, are only incidental and not of any importance, since they do not affect the color, which is simply due to the action of a proteolytic enzym in the seed.

The principal conclusions reached by Harrison^a are that the process of "fermentation or sweating in cacao consists in an alcoholic fermentation of the sugars in the pulp of the fruit accompanied by a loss of some of the albuminoid and indeterminate nitrogenous constituents of the beans, * * * and some parts of the carbohydrates other than sugars undergo hydrolysis and either escape in the runnings from the boxes in the form of glucose or undergo in turn the alcoholic and acetic fermentations." Further he declares: "During this change some of the astringent matters, to which the somewhat acrid taste of the raw beans is due, are also hydrolyzed, and thus a marked improvement in flavor is gained." Finally he adds: "This work has necessarily only resulted in a partial and incomplete study of the results of the fermentation."

The so-called fermentation is carried out either by heaping the fresh seeds, after separating them from the shell, on the floor or in receptacles and covering them with banana leaves or with cloth. The floor or the receptacles slope so that the watery products can escape during the fermentation. A period of two to six days, according to circumstances, is usually allowed for fermentation. The height of the heaped seed measures 1 to 1.5 meters and over. In some countries the highest temperature allowed for fermentation is 45° C., in others 50° C. According to Hart^b there is "danger in allowing [the temperature] to rise above 140° F. [60° C.], as the character of the product is sure to suffer." An apparatus has been recently devised by M. Schulte in which a constant temperature of 60° C. is maintained. In this case the yeast is fully excluded and bacteria with few exceptions also, and the necessary changes are brought on mainly by the heat, but this method has been considered too tedious and of little value to cacao planters, as is shown by Maurice Montet^c in his criticism of the apparatus.

The rise of temperature amounts to about 5° C. in twenty-four hours, and after four days the fermenting beans show generally an elevation of 18° to 20° C. above the temperature of the surrounding atmosphere. The more or less rapid rise of temperature in the

^a Proc. Agr. Soc. Trinidad, 2 (1896-97), p. 250; Hart, Cacao. Trinidad, 1900, 2. ed., pp. 106, 107.

^b Cacao. Trinidad, 1900, 2. ed., p. 42.

^c Jour. Agr. Trop., 5 (1905), No. 52, p. 297.

fermenting pile depends, of course, upon the height of the pile and upon the temperature of the surrounding air.

The cacao fruit resembles a cucumber in shape, but the form is subject to certain variations. The shell is of violet, red, or yellow color, sometimes even nearly white, 15 to 25 centimeters long and 6 to 10 centimeters thick. The shape of the seed is more or less round, often laterally compressed or flattened, when it resembles the bean of *Phaseolus*; its length varies from 2 to 2.5 centimeters, the diameter from 0.8 to 1.8 centimeters. Between the fleshy and corrugate cotyledons, showing convolutions on the surface, lies the bitter, purple

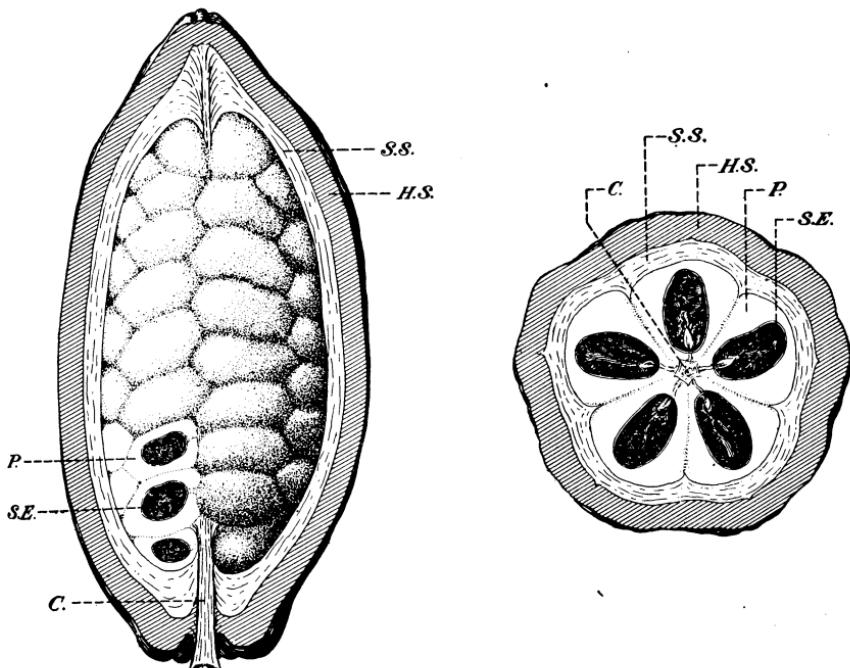


FIG. 1.—Structure of cacao fruit: *H. S.*, Hard outer shell of fruit; *S. S.*, soft inner layer of fruit shell; *P.*, pulp of seed or slime tissue; *S. E.*, seed with testa or envelop; *C.*, core or placenta.

embryo with its white chalaza. The cotyledons of one variety are white in color. There may exist in one fruit as many as 50 seeds. The loose parenchymatous slimy tissue (pulp) surrounding the testa of the seed appears to be of similar nature to the tissue forming the soft inner layer of the hard fruit shell. The structure of the entire fruit is somewhat complicated, and nature has evidently taken much pains to protect the embryo by four different envelopes. Figure 1 will suffice to explain the structure.

The chief purposes of the fermentation process are:

- (1) Removal or contraction of the pulp surrounding the seeds.

(2) Loosening of the connection between the seed and its testa.

(3) Development of color and improvement of taste.

Some authors hold that the heat of the fermentation is required to harden the interior of the bean, and also pass it to a second fermentation; further, that another change consists in the hardening or toughening of the testa of the bean, whereby brittleness is avoided during drying, and thus the seeds are better protected against the entrance of mold fungi.^a Various authors also ascribe to the fermentation a great influence upon the development of the aroma.

As regards the first of the above-named purposes, namely, the removal of the slime layer attached to the seed coat, a somewhat similar process occurs in the fermentation of coffee. (See p. 52.) The first step is the development of numerous yeast cells, which find ample nutrients in the sweet juice oozing from the pulp. The yeasts are chiefly *Saccharomyces ellipsoideus* and a certain amount of *S. apiculatus*, which develop rapidly. These organisms occur on fruits, as well as in the dust of the air and on the surface of the soil, together with numerous bacteria. The alcohol formed in the fermentation of the sugar by these yeasts destroys the superficial strata of the pulp or slime tissue, and as its juice passes freely to the outside, nourishment is given to innumerable bacteria, among them the widely distributed acetic bacillus. The respiration of these organisms and the fermentative activity generate heat and gradually a considerable elevation of temperature is reached.

The juice on the surface now assumes a strong acid reaction, due to the oxidation of alcohol to acetic acid, and this suffices to destroy the remaining cells of the slime layer, causing thereby a considerable shrinkage of it and also a further discharge of juice, as the cytoplasm of the dying cells becomes permeable to the interior juice. Thus a considerable amount of liquid gathers at the bottom of the receptacles and, since this liquor has an agreeable sour smell and taste, it is used in some factories as vinegar. By the bacterial action the attached pulp is further loosened from the testa to some extent and can be washed away, as is done in Ceylon. In many parts of Central America, however, the shrunken pulp is dried with the beans, which are shipped in this condition to other countries.

The fermented and well-washed cacao beans show a uniform yellowish or brownish coloration of their testa. The testa of unwashed fermented beans do not show a uniform coloration on account of the adhering films of fermented and shrunken pulp, which has turned from the original colorless condition to a violet brown color, and which is reduced from the original thickness of 0.1 to 0.2 centimeter to a mere film. An advantage of removing the remaining films by washing consists doubtless in the greater rapidity of drying, whereby

^a Hart, Cacao, Trinidad. 1900, 2. ed., pp. 35, 49.

the danger of attack by mold fungi is diminished. E. Lange^a holds that the extra trouble is not compensated by the additional price obtained for washed cacao. Nevertheless, the washing of the cacao has been recently introduced in Trinidad.

When pulped cacao is not fermented, but simply dried in the sun, the slimy layer around the testa shrinks considerably, but not to such insignificant thin films as after fermentation. When the entire juice of the slimy layer is simply dried up instead of being removed, a hygroscopic condition of the product results, which in moist weather becomes sticky and might support fungus growth. Hence, fermentation is preferable to a simple drying process, and after washing yields a much cleaner product.

In the fermentation of coffee the slimy layer to be removed from the testa (parchment envelope) is much thinner than that of the cacao seed. Hence, the fermentation of coffee is of much shorter duration than that of cacao.

In regard to the second purpose above mentioned, namely, loosening the connection between the seed and its testa, it must be mentioned that by the death of the seed, caused by the elevation of temperature of the fermentation to 40° to 45° C., some contraction takes place and the seed recedes somewhat from its walls. Later on, in the manufacture of cacao from the fermented and dried beans, they are roasted and some further contraction of the seed is caused. The testa having lost its hygroscopic water by the heat, now can be easily separated, especially while still warm and brittle.

An important change also due to the fermentation process is the production of a fine brown color. The effect of the fermentation in this direction is, however, not a direct, as supposed by many, but an indirect one, and may be secured by simply drying the bean. Sun-dried beans are uniformly deep brown. When the fresh seed is cut, the surface thus opened will turn from the original violet to a deep brown color within a short time, while boiled seed thus treated will not show any change of color, even after many hours' exposure to the air. This is in full analogy with similar phenomena observed very frequently with plants, and is due to the presence of oxidases or oxidizing enzymes. When cells are killed by being cut open or in any other way that will not injure the oxidases, these will, upon the death of the protoplasm in which they were stored up, be liberated and commence at once their activity, easily recognized by the early appearance of a brown, black, or red color. These colors are generally due to the oxidation of various kinds of tannins originally present in the juice or cell sap.^b If, however, the death of the proto-

^a Agr. Record [Trinidad], 4 (1891), pp. 105-107.

^b Such a case is observed in the curing of tobacco, whereby a fine brown color is produced.

plasm is produced by strong acids or boiling temperature,^a the oxidases will also be killed and no color change will be noticed, as the tannins and other readily oxidizable matters in the juices can not easily take up the atmospheric oxygen without the assistance of oxidases.

A further control experiment was made in which the pulped cacao (seed with testa and attached slime layer) was boiled for about twenty minutes with dilute sulphuric acid of 2 per cent. The slimy tissue contracted and together with the swollen testa was easily separated from the seed. These seeds showed a pure red coloration on the outside, while the interior was violet, and no trace of brown color appeared even after many hours exposure to the air, since the oxidizing enzym (oxidase) had been killed, together with the living matter (the protoplasm of cells).

The seeds commence to die when the entire fruit is kept for several days at 40° to 45° C., and the browning can be observed progressing from the surface of the seed toward the interior. By becoming overripe, the soft interior strata of the fruit shell, as well as the slime tissue around the seeds, contract more or less and a hollow space is formed between the fruit shell and the seeds with their adhering slime tissue. Air diffuses into this space, and the reason for the brown color produced by oxidation within the fruit becomes apparent. During the fermentation process the browning does not often go farther than this, and the interior of the seed often continues to show the original violet coloration. It is then that the subsequent drying process, which admits air abundantly by diffusion through the testa, completely finishes the browning process. Some further darkening can take place during the roasting process when powdered cacao and chocolate are made from the fermented beans.

The color change of the cacao seed is no doubt similar to the color change in the preparation of black tea, for which it has been positively proved^b that an oxidizing enzym acting on a specific tannin is the real cause of the blackening of the leaves. When the oxidizing enzym of the tea leaves is killed by steam, the leaves retain their green color and never turn black (green tea).

Tea leaves contain 7 per cent tannin and over, and the production of a black color from this tannin commences as soon as the leaves die, which takes place when they are kept in heaps after picking and are deprived of sunlight (death by starvation). Indeed, black tea contains less tannin than green tea. In order to increase the black coloration the leaves are rolled, which brings their juice to the surface, and the access of air accelerates the blackening process.

^a The killing temperature for oxidases is 20° to 30° C. higher than that for protoplasm or living matter.

^b K. Aso, Bul. Col. Agr. Tokyo, Imp. Univ., 4 (1900-1902), p. 255.

A case in which tannin is changed by partial oxidation for the sake of removing the astringent taste is observed in the curing of the fruit of certain varieties of persimmon (kaki) in Japan. By the curing process, which consists in keeping the fruits in vapor of alcohol or in subjecting them to slow desiccation in the sun, the tannin is changed, in contact with an oxidizing enzym and oxygen, to a brown, tasteless substance.^a The fruit thus acquires an agreeable taste.

Since a moderate brown color is also produced in white "nibs," free of cacao red, it follows that the brown coloration is not due exclusively to a change of cacao red. If the production of the color is due to an incomplete oxidation of the tannin, then there will be less tannin found in the cured cacao than in the fresh cacao. This agrees, indeed, with some analytical determinations of J. B. Harrison, published by Hart.^b The fat content is assumed not to change during the curing process, and this is in all probability the case. The data compiled under this condition are as follows for Calabacillo cacao:

Analyses of Calabacillo cacao.

Constituents.	Fresh.		Cured.		Constituents.	Fresh.		Cured.	
	Per ct.	Per ct.	Per ct.	Per ct.		Per ct.	Per ct.	Per ct.	Per ct.
Fat.....	29.25	29.25			Glucose.....		0.99	0.60	
Tannin.....	5.00	3.61			Hemicelluloses.....		5.11	3.74	
Cacao red.....	2.95	1.39			Woody fiber.....		8.03	2.78	
Theobromin.....	1.35	1.00			Protein.....		6.60	4.42	
Caffein.....	.11	.03			Amido compounds.....		.58	2.06	
Starch.....	3.76	3.22							

A part of the changes brought about by curing is probably due to the action of the living cells in the seed, before they are killed by the rising temperature. This would account for the decrease of starch, glucose, and hemicelluloses, which may be consumed by the respiration process, but the other changes are due to several enzymes. A proteolytic enzym brings on the decrease of protein and the corresponding increase of amido-compounds, while oxidizing enzymes, generally liberated from the protoplasm upon its death, cause the decrease of tannin and cacao red and their change to other compounds. The most conspicuous changes are, therefore, only possible after the death of the protoplasm, which is a desirable factor. Hence, it is a mistaken idea of Zipperer that the changes are due to a germination process of the seeds. He has even attributed the rise of temperature of the fermenting pulp cacao to this process, considering it analogous to the behavior of barley on the malting floor. This error can only be explained by the fact that he has never witnessed the fermentations

^a S. Sawamura, *Ibid.*, 5 (1902-3), p. 237.

^b Cacao. Trinidad, 1900, 2. ed., p. 100.

of cacao or coffee; for germination changes are not in the least apparent.

Another result is the change of flavor. In the fresh state the seeds have a raw, bitter, and astringent flavor, while after fermentation and drying the bitter and disagreeable taste has entirely disappeared. This change is doubtless due in a certain measure to the decrease of tannin; that is, to its change by oxidation to a brown substance, as in the case of the persimmon fruits, mentioned above.^a The flavor of the fermented beans is still far different from that of the prepared cacao product, which is produced by roasting the fermenting beans: hence a part of the taste must be due to changes caused by the heat of the roasting process.

The presence of oxidizing enzymes in the seeds of cacao can be proved by the usual reaction. Upon moistening a freshly cut section of cacao seed with tincture of guaiacum resin, just after taking the seed from the ripe fruit, a blue color is rapidly produced, first and most intensely in the chalaza of the embryo and gradually spreading over the entire seed tissue; also, the placenta shows soon an intense blue color. When a cross section through the whole fruit is moistened with guaiacum tincture, the chalaza of the embryo and the interior soft stratum of the fruit shell become rapidly and intensely blue, then follow in order the coloration of the convolutions of the cotyledons of the seed and the tissue of the hard outer shell. Finally the whole surface of the section of the seed and the exposed tissue of the testa become blue; but the slime tissue or pulp around the testa remains perfectly colorless, presenting a most striking contrast.

If the tissue of the seed is crushed with some water in a mortar, the filtered liquid will show no blue coloration on addition of guaiacum tincture and shaking with air, while the unfiltered liquid will become blue very soon. This shows an exceptional case, namely, that the oxidase (laccase) is present in an insoluble state and perhaps held in combination with an insoluble protein.^b Upon standing the blue color, obtained with the unfiltered liquid, will gradually disappear, except on the surface, but on adding a few more drops of the reagent and shaking, the intense blue color reappears. This phenomenon is due to the presence of a reducing compound in the juice.

In testing for a second oxidizing enzym, the peroxidase, the tissue of the seed, crushed with a little water, was heated for five minutes to 75° C. and one portion of this liquid was filtered; the other not. The test with guaiacum tincture yielded no blue reaction in either liquid, proving that the oxidase was killed, while on addition of a little peroxid of hydrogen the unfiltered juice gave an intense blue reaction.

^a The opinion of Harrison mentioned above that the decrease of the astringent taste is due to a hydrolysis is erroneous and would be without analogy.

^b This recalls the existence of a soluble and insoluble form of catalase.

and the filtered juice showed only a trace. This difference proves that the peroxidase, like the oxidase, was present, but retained as an insoluble compound—an exceptional case.

Reactions with guaiacol were also tried. This substance produced no coloration when applied by itself, but in conjunction with hydrogen peroxid a red color turning to brown was soon produced in both the hard as well as the soft layer of the fruit shell. Later, in the testa and the seed in general, as well as in the slime tissue covering the testa, only a weak, reddish coloration was produced. This peroxidase reaction agrees also with that just mentioned, in so far as the slime tissue gave only an exceptionally weak reaction compared with all other parts of the fruit. The slime tissue of the coffee fruit is also poorer in oxidase and peroxidase than the other tissues.

The further generation of the characteristic aroma of cacao is of great importance. Is this process due to the action of an oxidizing enzym or to that of a hydrolizing enzym, and does the fermentation influence the generation of aroma only indirectly by the development of heat or directly by furnishing some compound? Or, is the roasting of the fermented cacao beans alone responsible for the aroma? The investigations thus far made do not solve this problem satisfactorily. It may be mentioned, however, that Hart^a agrees with Chittenden,^b who declared that after a certain stage of the fermentation "the cotyledons are found separated and the vinous liquor of the pulp, which passes through the membranous covering, occupies this space as well as the cavities between the convolutions. * * * This it is which has so marked a physiological influence and affects its flavor, the bean being, as may be said, 'stewed in its own juice.'"

According to the laws of osmosis some acetic acid and some alcohol from the fermenting liquor will doubtless enter through the testa and come in contact with the cotyledons, which thereby may be killed, if the temperature of the fermenting mass has not already accomplished this. The reaction of the cotyledons after drying the fermented beans is acid, but whether this is wholly due to the entering acetic acid may be doubtful, since the reaction is weakly acid in the fresh state. A stronger acid reaction is shown by the slime tissue.

The expression "stewed in its own juice" used by Chittenden can hardly be admitted, since the juice of the pulp, after being entirely decomposed by yeast and bacteria, is certainly not the "own juice" of the cotyledons. Still, that author attributes to it the generation of the flavor.

^a Cacao. Trinidad, 1900, 2. ed., p. 38.

^b Agr. Record [Trinidad], 2 (1890), p. 110.

The opinion of J. B. Harrison (see p. 42) that the decrease of tannin during the fermentation process stands in relation to the development of aroma (see p. 48) is certainly far from the mark, as tannin can not produce ethereal oils by any oxidation or fermenting process. Only color and taste stand in this relation to the tannin content.

Several experiments were made by the writer with an aqueous solution of 1 to 4 per cent acetic acid containing from 3 to 5 per cent of alcohol in order to imitate the composition of the fermenting pulp juice. After twenty to thirty hours digestion of pulped cacao at 40° to 44° C. it was observed that the pulp had died and shrunk to skinny masses, partly separating in small pieces, but mostly still firmly adhering to the testa. It appears that for bringing about an easy separation of the dead pulp from the testa a bacterial enzym is necessary, as in the case of coffee fermentation. It was further observed that the amount of acetic acid, which entered by osmosis through the testa to the cotyledons, was not sufficient to kill the oxidizing enzym, since the freshly cut surface of these seeds rapidly turned brown on exposure to the air. On the other hand, it was observed that when the freshly cut surface of the seeds so treated was moistened with 4 per cent acetic acid no further change by oxidation took place. In this case the oxidizing enzym was killed.

It is stated by Hart^a that "of late years there has been a large amount of inquiry for cacao which is but slightly fermented or not fermented at all." This renders it very probable that the decomposed juice of the slime tissue is not required for the generation of the aroma, as was supposed. Indeed, the true aroma of cacao is faint before roasting the fermented beans. The case is, therefore, similar to that of coffee, and is different from that of tea. With tea the aroma is the result of the action of a hydrolizing enzym, yielding the volatile tea oil, as was shown by Katayama.

That the aroma of the cacao is chiefly produced during the gentle roasting process is the opinion of manufacturers of chocolate from the fermented beans. The fermentation seems, indeed, to have nothing at all to do with the production of aroma. Seeds simply dried in the sun and then gently roasted may yield an especially rich and aromatic chocolate, as Safford^b has also indicated. Hart says:

No adulteration * * * is equal to the flavor of the virgin cacao, provided the essential oil has not been destroyed during the process of roasting during which process it appears to be developed.^c

The question now arises, Which compound yields the aroma in the cautious roasting of the fermented cacao beans? It is certainly not

^a Cacao. Trinidad, 1900, 2. ed., p. 33.

^b Compare the quotation in the introductory remarks to this article.

^c Cacao. Trinidad, 1900, 2. ed., p. 111. These words contradict his other opinion, however, quoted above in regard to the influence of fermentation on aroma.

a glucosid, for neither the testa nor the cotyledons of the beans develop anything like a cacao flavor upon being boiled for some time with dilute sulphuric acid (3 to 6 per cent). The same negative result was obtained by boiling those materials with moderately concentrated solution of caustic potash. It seems probable that it is a certain concomitant of the fat which causes the production of the flavor, after being moderately oxidized during the drying of the beans. Only seeds in which the oxidizing enzymes have produced changes can yield the true aroma by roasting, not the fresh beans.^a

In the manufacture of the cacao powder of commerce the fat of the cacao is removed more or less, since a suitable powder can not otherwise be obtained, but in the direct manufacture of chocolate this removal of the cacao fat can not be justified. It is claimed that cacao fat or cacao butter is difficult of digestion, but in reality cacao butter is as easily digestible as cow's butter. Besides, the removal of fat also diminishes the aroma of the chocolate. In the manufacture of chocolate in Porto Rico, fermented cacao seeds are placed in a small baker's oven for about one hour, until the testa have become very brittle and can be easily removed. This roasting temperature is kept considerably lower than that required for baking bread. The cacao butter is not removed in Porto Rico, and therefore the chocolate manufactured there has an exquisitely fine aroma.

SUMMARY.

The fermentation process itself is due in the first place to yeast cells which multiply rapidly in the saccharine juice oozing from the pulped cacao and produce alcohol and carbon dioxid. In the second place bacteria participate, which develop rapidly after a certain time, and change the alcohol formed by the yeast by oxidation, either wholly or partly, into acetic acid. These processes cause a rise of temperature and the death of the cells of seed and slime tissue, whereupon the juice of the slime tissue, more or less altered, collects at the bottom of the receptacles, together with the acetic acid produced.

The chief object of the fermentation is to shrink the slime tissue or pulp attached to the testa of the seed, allowing the remnants either to be washed away, as is done in Ceylon, or dried upon the seed, forming an irregular brown film upon the testa. The advantage of thus changing the voluminous slime tissue lies in the increased facility of quickly drying the seed. In this regard there exists a close analogy to the fermentation of coffee. The loosening of the adhe-

^a Fresh beans were crushed, washed with alcohol, and extracted with ether. Neither the extracted fat nor the seed powder developed on moderate heating any flavor resembling that of cacao; only the alcoholic extract yielded thus a very faint flavor of cacao. On evaporation of the alcoholic extract another aromatic odor is noticed.

sion between seed and its envelope and the hardening of this envelope (testa) are claimed as further effects of fermentation.

The fermentation has also an indirect influence on changes going on within the seed, inasmuch as by the temperature produced (40° to 50° C.) the cells of the seeds are killed, thus liberating the oxidizing enzymes, which cause the formation of the brown color, by oxidation of the tannin of the seed. This brown coloration is increased during the drying process and finally by the roasting.

The taste of the raw cacao bean is not only altered by the partial oxidation of tannin during the fermentation or sun drying of the seed, but also by products of roasting.

The action of oxidizing enzymes, as well as the final roasting process, play a part in the development of the aroma.

THE FERMENTATION OF COFFEE.

The so-called fermentation of coffee has thus far not been investigated, and has been defined sometimes as an "alcoholic fermenta-

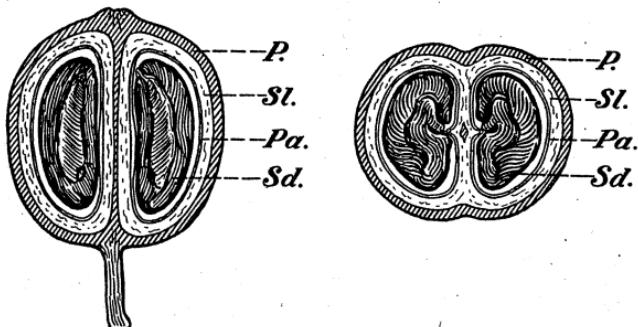


FIG. 2.—Structure of coffee fruit: *P*, pulp; *Sl*, slimy layer; *Pa*, parchment envelop; *Sd*, seed with silver skin.

tion necessary to remove the saccharine matter."^a Such saccharine matter, however, should be easily removable by simply washing with water. Upon close examination the writer concluded that the aim of the "fermentation" is the removal of a slimy stratum firmly adhering to the parchment envelope of the seeds. The removal of this is necessary, because the drying of the seed envelope would otherwise be very much retarded, and because a bad flavor may finally be imparted to the seeds by the partial decay of the slimy stratum during the drying process. The process will be explained by examining the anatomical structure of the fruit. (Fig. 2.)

Just below the skin of the fruit and extending between the enveloped seeds is a fibrous tissue containing a sweet juice. This pulp, together with the skin, is easily separated by mechanical means from

^a Cf. Watt, Dictionary of the Economic Products of India, Calcutta, 1889, vol. 2, p. 476.

the seeds, which are enveloped in a hard parchment. Adhering to this parchment is a stratum of very slimy cells, the slime layer.

The preparation of coffee for market requires the following manipulations:

- (1) Pulping to secure removal of the skin with the adhering tissue.
- (2) Fermentation to separate the slimy layer from the parchment envelope.
- (3) Washing away the loosened slime.
- (4) Drying the envelope around the seeds, preparing for the necessary brittleness for the next operation.
- (5) Hulling or milling, consisting in the removal of the parchment envelope, with subsequent subjection to a fan to blow away particles of parchment envelope and silver skin.

The entire fruit is often called "cherry" from the similarity of form and color. The expression "pulped coffee" signifies seeds in the parchment envelope with slimy layer. "Coffee in parchment" means the product after pulping, fermenting, and drying. The "bean" means the seeds deprived of parchment and silver skin.

Fruits of red or yellow color should be picked for pulping, as only such furnish seeds of the desired bluish-green color. Green unripened fruit containing a hard pulp and little or no sugar should be excluded, but such fruit can not be entirely avoided, since some unripened seeds will drop off in gathering the ripened ones.

The fruits are well moistened with water when passing through the pulper, which easily separates the skin and fibrous layer. Attached to the pulper is a conical sieve ("separateur") placed in a horizontal position, which retains the fruits which have accidentally escaped pulping, and they are carried back to the pulper.^a

In order to understand the fermentation process it must be remembered that on the surface of all sweet fruits are a great many yeast cells and bacteria. When by the pulping the sweet juice is forced out and spread all over the separated skin, and over the pulped coffee, it is not surprising that these organisms develop rapidly. The sweet

^a It has been proposed to dry the pulp and bring it into commerce as a cheap substitute for coffee. When pressed well to remove the caffeine and mixed then with molasses, it might serve as a food for hogs. Greshoff holds that the best application is as a manure and gives the following composition in the air-dry state:

	Per cent.
Caffein	1.1
Carbohydrates	23.3
Albumin	7.6
Cellulose	16.1
Water	14.9
Fat	3.3
Ash	6.9

juice not only contains sugar, but also some nitrogenous and mineral matters required for the development of organisms.

An examination of the skin with a high magnifying power several hours after pulping shows numerous cells of *Saccharomyces*, which in form resemble chiefly *Saccharomyces ellipsoideus* and sometimes also *S. apiculatus*.

Numerous bacteria are also present. Alcoholic fermentation can soon be detected by the vinous odor, and the fact that the fermentation produces heat explains why the temperature of such a heap of pulp rises considerably after a time. A heap of nearly 30 centimeters in height showed after sixteen hours a temperature of 41° C. at an air temperature of 26° C. Later, acetic acid is formed and the red color of the skin is changed to a brownish one.

When the pulped coffee, on the other hand, is examined, few yeast cells and bacteria are noticed on the slimy stratum after one hour, while after sixteen hours an immense increase has taken place and not only is considerable alcohol formed by the yeast cells, but also acetic acid by certain bacteria. Mycoderma and the mycelium of fungi are occasionally seen. Litmus is reddened intensely and the odor of acetic acid is readily discernible. At the same time another volatile product is formed in small quantity, which modifies somewhat the acid odor.

The alcoholic fermentation of the sugar adhering to the slimy stratum, as well as the further oxidation of the alcohol to acetic acid, and finally the respiration process carried on with considerable intensity by all these organisms; cause a rise of temperature, depending upon the depth of the stratum and the temperature of the surrounding air. The heaps of pulped coffee are generally 1 to 2 feet high. In such heaps the temperature was found after fifteen to sixteen hours to range from 34° to 42° C. at an air temperature of 25° to 29° C.

The alcoholic and acetic fermentations proceeding in the heaps of pulped coffee are, however, not the most essential phenomena; the most important point is that the slimy stratum is separated from the parchment envelope. It is by no means dissolved, but merely loses its firm adhesion and is left loosely spread upon the parchment coffee so that it can easily be washed away by a current of water and the parchment coffee dried.

Neither the acetic acid nor the enzym already present in the slime causes the separation of the slime layer, as tests have shown.

Freshly pulped coffee was kept in dilute acetic acid (about 1 per cent) at 35° to 40° C. and another portion in some water containing a few drops of ether to prevent bacterial growth. In both cases the slimy layer was found still firmly attached to the parchment after twenty-four hours. This leaves no other inference but that a peculiar enzym dissolving the adhesive substance (a carbohydrate?) between

the parchment and the slimy stratum was furnished by the bacterial growth, or, what is less probable, by the yeast cells.

The "fermentation" should not take longer in Porto Rico than fifteen to twenty hours, while in some sections of Central America, as Guatemala, it must be carried on for two days.

Undue prolongation of the fermentation must be avoided, as otherwise a brown coloration of the parchment and of the seeds is produced; the seeds further acquire a disagreeable odor—two circumstances which render the product unfit for the market.

After the fermentation and washing the parchment coffee is readily dried, either on cement floors exposed to sun and air, or better in rotating cylinders through which warm air passes. At a certain degree of dryness the parchment becomes brittle and breaks easily in the milling process, which thus removes the parchment envelope and silver skin from the seeds. In fact, the milling must be done while the parchment is still warm.

This milling is in many cases done in London and not in the country where the coffee is produced. Better preservation of shape and color of the bean has been observed when the latter is protected for a time by the parchment envelope. The cost of transportation is in this case a little higher, but it does not come into consideration, as from \$2 to \$3 more has been realized per hundredweight for coffee thus treated than for that cured in Central America.

In reviewing the so-called fermentation of coffee the conclusion is inevitable that alcoholic and acetic fermentations are not of direct benefit, but only indirect, inasmuch as heat is thereby produced which supports the action of a body (enzym) furnished by the bacteria, which dissolves the adhesive substance between parchment envelope and slimy layer.

Issued September 1909

PORTE RICO AGRICULTURAL EXPERIMENT STATION

D. W. MAY, SPECIAL AGENT IN CHARGE.

UNIV. OF VIMS

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ANNUAL REPORT

OF THE

PORTE RICO
AGRICULTURAL EXPERIMENT
STATION

FOR

1908.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, Chief of Division of Insular Stations, Office of Experiment Stations.

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LETTER OF TRANSMITTAL.

PORTE RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., January 12, 1909.

SIR : I have the honor to transmit herewith and recommend for publication the Annual Report of the Porto Rico Agricultural Experiment Station for the fiscal year 1908.

Respectfully,

D. W. MAY,
Special Agent in Charge.

Dr. A. C. TRUE,

Director Office of Experiment Stations,

U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON,
Secretary of Agriculture.

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ANNUAL REPORT OF THE PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1908.

SUMMARY OF INVESTIGATIONS.

By D. W. MAY, *Special Agent in Charge.*

INTRODUCTION.

Continued progress may be reported in agricultural conditions in Porto Rico. This may be noted in the general growth in prosperity of the whole island and is further evidenced by the increase in exports, all of which are agricultural products. A constant increase may be noted in the value of exports from the year 1901 to the present. During 1901 the value of merchandise exported was \$8,549,093. During the year 1908 the value of the exports was \$30,601,639. This latter sum represents an increase over the exports of 1907 of \$3,637,022.

The total value of the exports does not tell the whole story. The home consumption of many articles produced has greatly increased. This is due to the fact that the general prosperity of the whole mass of the population has been bettered, thereby increasing its purchasing power. The exports of some articles have fallen off owing to local demand. In 1901 there were exported cattle to the value of \$457,983, while in 1908 the export of cattle was valued at only \$600.

The matter of greatest importance to the station during the fiscal year was the providing of additional funds by congress for carrying out work already inaugurated and permitting the study of other questions of no less value to the progress of agriculture and the benefit of the Island of Porto Rico. Second in importance was the appropriation made by the insular legislature of \$20,000 for the erection of a building for the exclusive use of the experiment station. Since its inception, the work of the station has been carried on in an old sugar mill that stood on the plantation and which is wholly inadequate to the growing needs of the station. The erection of the new building, to be of cement construction and to stand on an elevation near the building now used for that purpose, is under way. This building, while supplying a very urgent need of the experiment station, is also an indication of the appreciation of the work of the institution by the people of Porto Rico.

During the year a chemical laboratory was installed, equipped with a gas plant and water. This has been placed temporarily in the old sugar mill building until the new home for the use of the station shall be erected. A warehouse building has been constructed for the housing of fertilizers and machinery. This

has been built partly of brick, which were made upon the place. A dairy barn and silo have also been erected.

The work of the station during the year has been essentially along practical lines. Agriculture in the Tropics has not had the study that it has received in the Temperate Zone. Many methods that are followed in more advanced countries of the world are still the subject of experiment in the Torrid Zone. It is necessary not only to study the improvement of agricultural operations under entirely new conditions but to prove the wisdom of the application of certain well-known principles that obtain in temperate regions.

The greatest need in agriculture in the tropical regions of the earth is the improvement of the economic plants and animals, in other words, plant and animal breeding. The economic plants and domestic animals usually show, either no improvement, or else a positive degeneration. No other line of work promises such a reward for patient endeavor as the improvement of the different varieties of economic plants and animals. With a continuous growing season, plants are allowed to produce decreasing harvests from year to year through ratoon crops instead of being more frequently planted. Again, as seed time follows closely on harvest, economic plants are grown from bulbs or cuttings to a greater extent than in the Temperate Zone. This has a tendency to give decreased yields and to produce plants of lessened vitality. One of the principal lines of work, therefore, of this station is the propagation and dissemination of plants and animals of greater productivity.

Among the plants that are being improved by selection and breeding are the following: New varieties of sugar cane grown from seed, pineapples from seed; the cowpea for the purpose of producing a variety best adapted to the soil and climate of Porto Rico; improved strains of muskmelons, cucumbers, sweet corn, and other vegetables.

Of no less importance to Porto Rico is the introduction of economic plants of other countries. (Pl. I. fig. 1.) This line of work has been extended to a great degree during the past year, and some of the plants mentioned in former reports have fruited for the first time in the trial grounds. It has been necessary to lay out a new orchard to receive the varieties of citrus and other fruits that have been introduced. Twenty-four additional varieties of mangoes have been received and planted. One hundred more trees of the grafted Indian mango have been planted in the grounds of the station, while a number have been sent out to different sections of the island for trial.

Special attention has been paid during the year to the introduction and propagation of forest trees. There is a considerable area of land in Porto Rico, lying between the fertile cane fields of the coast and the coffee groves of the interior, that yields a very small revenue to the owners. These hills and mountains have been denuded of their forest growth and because of heavy rains have become almost worthless. Experiments indicate that such areas can be reforested and that in this and no other way can they be brought to a state of productivity. Al-



FIG. 1. ONE OF THE STATION PLANT HOUSES.

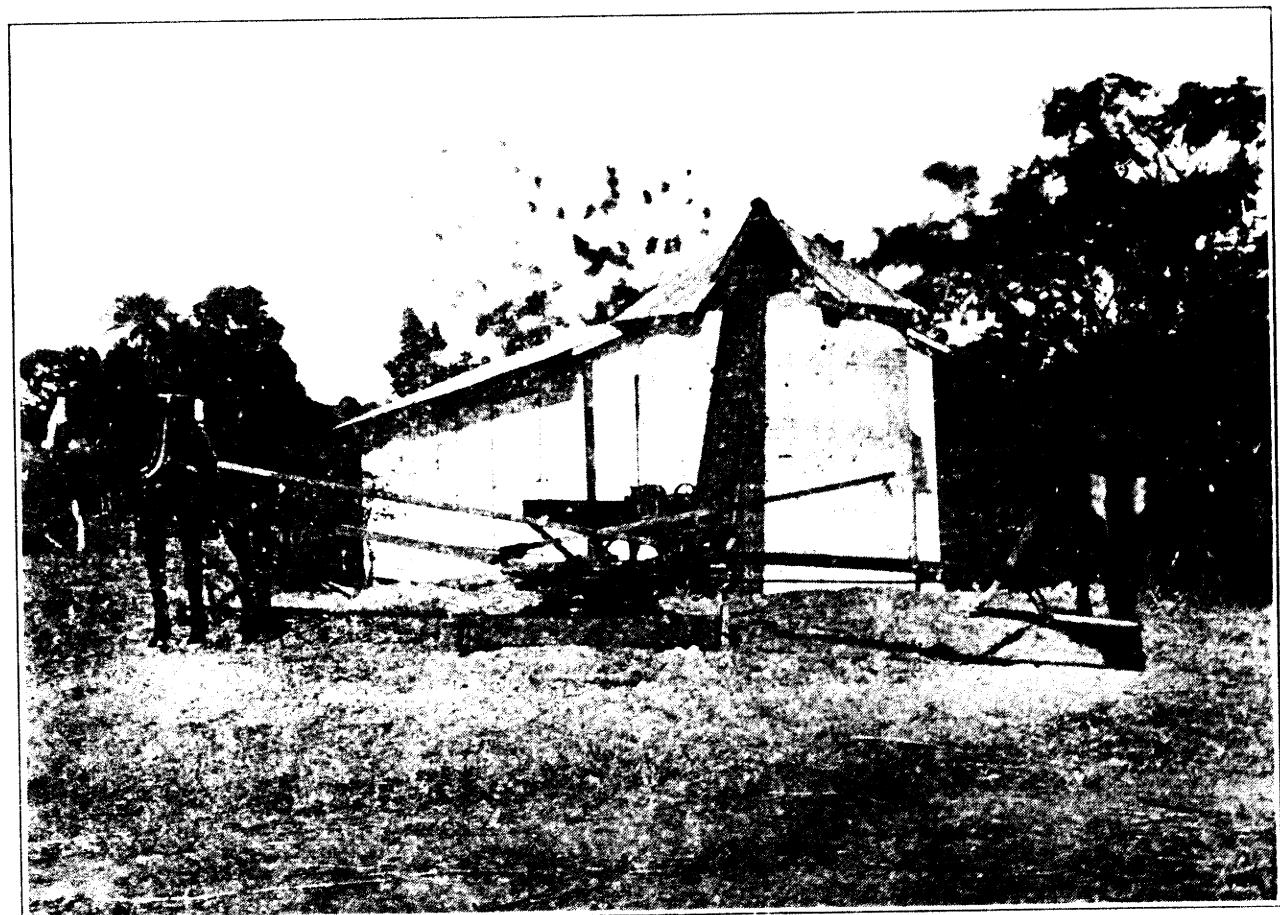


FIG. 2. SILO, SILAGE CUTTER, AND ELEVATOR.

ready a number of hills of this description on the station farm are showing the results of planting. Among the more promising trees may be mentioned the Indian mango, the eucalyptus, and the mahogany. On low grounds of the station there have also been planted groves of *Castilloa* rubber, cacao (some twenty varieties), and cocoanuts.

During the year a trip was made by the special agent in charge to the Leeward and Windward islands and the Spanish Main, visiting the British and French stations and Venezuela. As some of these stations have been established for more than a quarter of a century, a great deal of benefit was derived from their personal inspection and a study of the results attained. The horticulturist also made a trip through Cuba and Florida for the purpose of studying the methods of growing citrus fruits and pineapples. As the pineapple industry has become a leading one in Porto Rico, it was especially necessary to make a personal study of the methods of handling old pineapple plantations to obtain continued favorable results.

It has been found advisable to take the experiment station to the plantations, and to best carry out this idea, cooperative experiments have been arranged in different sections with representative planters. These cooperative experiments are for the purpose of introducing new crops and studying methods for improving the soils both by fertilization and manipulation. These experiments are under the direction of a number of the station staff, but the expenses are borne by the planters. Many valuable results have been obtained not only for the plantation where they are carried out but also for the neighborhood. They form a focus where planters may meet with the members of the station staff to discuss the methods employed and the results obtained. Some results along these lines are very striking. In one series of experiments in the fertilizing of orange groves, it has been found that different elements of the fertilizer affect not only the shipping quality but the flavor of the fruit.

The growing appreciation of the Station and its work is shown by the largely increased correspondence and in the number of visitors during the year. Requests for personal inspection have been greater than it has been possible to supply. The extension of the Morrill Act to Porto Rico with the establishment of an agricultural college, which will be organized during the coming year, will render assistance to the station in putting its results before the people, and also in supplying trained agriculturists to meet the demands from progressive planters for skilled assistants.

The greatest need of the station at the present time is to secure and hold well-trained men in its service. When a vacancy occurs it usually takes a long time to fill it and much valuable work is stopped. Again, when good men are secured the service should be made so attractive that they would not leave it for any slight increase in salary or betterment of location.

The station is situated outside of Mayagüez, and it is somewhat difficult for the employees to go to and from the City to their work. Could funds be secured for the purpose, it would be

advisable to construct a building on the station grounds for the housing of such employees as cared to live there and where those living in the city could obtain luncheon at midday. Such a home would add greatly to the attractiveness of the service at the station. Occasionally experts from Washington visit the station for a greater or less time, looking into some special problems, and it would also be a great convenience if these investigators could secure comfortable temporary quarters. It would be to the advantage of the station to keep such men as long as possible and to give them every facility for carrying out their investigations.

SUGAR CANE.

The greatest export in value of Porto Rico at the present time is sugar. This has shown a continuous increase since the American occupation. In 1901 the value of sugar exported was \$4,715,611, in 1908 this amounted to \$18,690,504. The value of molasses exported has been fairly uniform for seven years, but showed a great decrease in the past year. The exports of molasses in 1901 were valued at \$595,902, and these figures varied very little from year to year up to 1908, when the amount fell to \$267,184. This is largely due to the manufacture of denatured alcohol, which is assuming some importance in Porto Rico. It is undoubtedly true that the abundant supply of low grade molasses furnishes one of the cheapest sources of denatured alcohol, and its consumption on the island is increasing rapidly. Some experiments made at the station show that it is by far the cheapest fuel available for cooking purposes. For many years Porto Rico has used charcoal in the kitchen and this has been largely responsible for the deforestation of the lands. Denatured alcohol is much cheaper than charcoal, and its use will prove an important factor in assisting to reforest many unproductive areas.

The increased production of sugar has been brought about by the planting of more lands and by increasing the productivity of those under cultivation. The extension of cane planting cannot be very much greater owing to the fact that available lands are already nearly all taken up. The possibilities of increasing the yield per acre are more promising. Porto Rico has long been famous for the richness in sugar of her canes. The continued cultivation of this crop for so many years indicates the inherent strength of the soil. By the application of the methods of scientific agriculture no doubt the former fertility of the lands may be restored and the fields brought to the front rank in the yield of sugar.

The results of experiments covering several years, which have been carried out in cane production at the station, have been incorporated in a bulletin soon to be issued. A few statements of the results may prove interesting here.

As regards climate there are two cane growing areas in Porto Rico, one is the dry section, extending along the entire southern coast, where irrigation must be practised to get the best results, and the other is the rainy section, on the north side and the eastern and western ends of the island. The interior of Porto Rico, while well watered, is so mountainous that the question

of transportation has precluded the growing of canes except in valleys here and there where there is enough land available to permit of the operation of small mills. One of the great needs of the dry section is more irrigation. Many of these fields are comparatively new and they need only an abundance of water to permit of the production of maximum crops. A number of irrigation plants are in operation, but they are inadequate to the needs of the lands available for cane production. Bonds have been issued by the insular government for diverting the Manati and other rivers to the south side of the island for irrigation purposes. This water will be sold to the plantations and the resulting revenue used for retiring the bonds. This project will result in greatly increasing the yields of the lands on the south side and add to the total production of sugar. These lands need fertilizer less than others that have been cropped for a long series of years.

In some cases the soils in the dry sections are impregnated with alkali. From the results of analyses made of a number of such soils, the planters are advised to use gypsum to correct this alkalinity and thus bring the soils into proper culture. The indications are that at a small cost these lands may be reclaimed.

Most of the soils in the regions of heavy rainfall are of a heavy tenacious clay. While fertilizers can be profitably used on most of them, at the same time it is highly advisable to improve their physical texture. The usual method of draining such soils is by open ditches, which must be made and cleaned continually and at great expense. In most of these lands tile drainage could be very profitably adopted. The tiling of the low lands at the experiment station has proved very successful and may be classed as a permanent improvement, obviating the constant necessity of cleaning open ditches. Some planters are putting in tile ditches and the results indicate this method of drainage to be highly profitable.

A great many of the heavy soils also require liming, not only to correct the acidity but to improve their physical condition and bring about better tilth. In lands where there is a great deal of organic matter, this has proved very profitable, and has reduced the fertilizer bill by putting the soils in such condition that small amounts of manures are more effective than large amounts were formerly. In many instances liming has preceded fertilizing because the physical condition was such that the sugar cane could not profitably utilize the fertilizers that were added.

Comparatively Porto Rico has been long settled and the soils are very much worn, needing in nearly all cases the three elements, nitrogen, phosphorous, and potash. Of all these elements, however, nitrogen is the most important and its application governs the production to a great extent. As long as present prices of sugar continue the lands now devoted to cane will continue to be planted to that crop. This production of the crop on the same land year after year is against the best practices of agriculture and cane growers must study methods of overcoming the drawbacks in soils continually subjected to a lack of diversification.

There is no resting period of several months, as is the case in the North, but when one crop of cane is removed another immediately follows either from the old stubble or from immediate replanting. To add nitrogen to the soil, a series of experiments has been begun at the station in which certain legumes are grown between the rows of cane. These are planted soon after the canes are cut and the period covered extends from 60 days with cowpeas to the entire year with the sword bean. These crops not only add to the soil nitrogen, which is very much needed by the cane, but they improve the physical condition of the land and doubtless remove some of the toxicity of the soil produced by the old cane roots, should any such exist.

In experiments in distances of planting, the close planting as is usually followed in Porto Rico has proved the most profitable method. The wide planting such as has been advocated in Cuba of late not only gave decreased yields but added to the expense of cultivation, owing to the fact that the malojillo grass had more sunlight and space between the rows of cane in which to grow.

The experiment station is carrying on the work of breeding new varieties of cane by planting the little seeds in the arrow, and some very promising new varieties have been developed. For several years the best seedling canes developed by the British stations, cuttings of which have been kindly sent us from time to time, have been grown and distributed. Some of these canes both in the laboratory and in car lots sent to the mill have proved much richer in sucrose than the old varieties of cane commonly grown in Porto Rico. Some of these canes in the island have run over 20 per cent of sucrose in the juice, and it is expected that further work along this line will finally develop varieties of cane that will average over 20 per cent sucrose in field trials.

TOBACCO.

The second export in value is tobacco. While the export of leaf tobacco has shown a great increase from year to year it has not kept pace with the increase in manufactured tobacco in the form of cigars. This is probably owing to the abundance of skilled labor available; and the export of cigars will likely increase over that of the leaf tobacco. At the experiment station the heavy soils do not produce a high quality of cigar leaf but produce a most excellent Burley plug tobacco. The sections devoted to the production of cigar leaf are in the interior, notably from Caguas to Aibonito. There has been a steady increase in the amount produced and also an improvement in the quality. The production of wrappers grown under cheese cloth is in the hands of large companies. Filler tobaccos are produced not only by the companies but by a great many small planters who either sell their product cured or as cut from the field. There needs to be more scientific study made of the tobacco soils of Porto Rico for the purpose of mapping them and more especially to determine their fertilizer requirements. Owing to the distance and cost involved, the experiment station has not been able to carry out any experiments in the tobacco districts during the past year. The Porto Rican American Tobacco Company has established an

experiment station near Caguas and during the coming year this station will cooperate with them in several lines of work. During the past year different members of the station staff visited the tobacco sections advising the planters in regard to seed beds, fertilizers, and the proper fermentation of the crop. Some analyses have been made of typical soils in the tobacco growing sections.

COFFEE.

There has been some slight improvement in the coffee situation in the last three years. Prices continue low, and owing to the heavy production of coffee in Brazil the outlook for the future is not bright. There has been some increase in the production brought about largely by cleaning, cultivation, and pruning of the existing coffee trees. Very few new trees are being set, and the coffee planters are seeking new crops to which to turn their attention. Under a separate heading will be found the report of the coffee expert showing the progress of the work at the substation in the mountains. (See p. 33.) Endeavor is being made to promote better agricultural methods with Porto Rican coffee. In the meantime in order to obtain better prices, it would be advantageous for the United States Government, by reciprocity treaties, to secure for Porto Rico more favorable trade relations with countries that consume its coffee. A large part of the coffee is sold to Cuba and the rest to France, Spain, and other countries of southern Europe. The value of coffee depends upon its flavor, and while Porto Rican coffee is one of the highest of a certain type, it is a class that is relished in some foreign countries more than in the United States. The consumers in the States prefer a highly flavored aromatic coffee like the Java. In order to meet this demand the experiment station has introduced and is growing the best quality of Javas. Coffee growers are very much interested in this work, and during the past year a great many seeds were distributed among them for trial. This seems the best way to meet the market of the United States.

FIBERS.

It has been proved that certain sections of Porto Rico are well adapted to the production of a very fine quality of sea-island cotton. This industry, however, does not make much progress. There is a lack of planters skilled in the production of this crop. Moreover, it is a crop requiring strong land and unremitting attention. Cotton growers are not disposed to spend such amounts for fertilizers as are found desirable in growing this crop on the sea islands of the Carolinas or in Georgia. With the same skill and attention in growing the crop, the returns in certain sections of Porto Rico would fully equal those obtained in South Carolina or Florida. The exports of sea-island cotton during the past year were \$64,677, which is over double the amount of the previous year.

Several hundred pounds of the best sea-island cotton seed received from the United States Department of Agriculture have been distributed among the planters. This is a crop adapted to

small holdings and an industry to be followed by the small farmer, as it requires but small capital and the women and children of the household can be employed in its production. It is a new industry, however, in most sections and gains ground slowly. Its especial needs are that the growers practice improved methods of tillage, the use of manures, and measures against the cotton caterpillar. In growing sea-island cotton in the States very large amounts of fertilizer are found necessary and planters must come to a realization that such must be used here to get high yields and the best quality of fiber. The well-known means of combating the cotton caterpillar must also be followed. This pest is to be expected and the planter should be prepared to meet it when it first puts in its appearance, otherwise severe losses will occur. The well-tested means if used promptly will easily keep this pest in check, and for that reason it is not to be feared as the cotton boll weevil which threatens the cotton industry in the Southern States but which does not occur in Porto Rico.

Another fiber industry that should prove profitable over certain areas in Porto Rico is the growing of sisal. This plant, which has proved very profitable in Yucatán, grows well in various sections of Porto Rico and its production should prove a paying industry in the dry limestone districts of the south side. The insular government has, through the experiment station, purchased 100,000 plants for trial and is seeking to interest capital in taking up the industry in the island. Being a crop new to Porto Rico, it is difficult to interest planters in the business, especially as it requires considerable capital and it is necessary to wait three years for the first returns. During the year 75 acres were planted to sisal under the direction of the experiment station on some government land in an arid section of the island. These plants are starting to grow with every promise of success. There is a great deal of land now lying idle that is valuable for this crop, and it is the purpose to make of the present planting a commercial trial. Many acres of land now nonproductive can be planted at a very low cost, it being found necessary only to cut and burn the brush, leaving a mellow and fertile seed bed.

The importation of the palm from which the Panama hats are made has proved successful, and a number of plants have been distributed among the producers of this class of fiber. In order to permit the making of the higher grades of Panama hats it will be necessary to grow the plants. An important industry of hat making has been operating for several years, the raw material being imported from Colombia. That country, fearing a loss of her leading industry, has put an export duty on the raw material, thus causing the closing of the several factories located in Porto Rico.

FORAGE CROPS.

Porto Rico possesses two splendid grasses, malojillo or Para grass and Guinea grass. Experiments are being continued at the station with the object in view of obtaining leguminous crops for improving the soil and also providing forage for animals. Of these the cowpea is the most promising. A number of other

leguminous crops imported from various countries are under trial. (Pl. II. figs. 1 & 2.)

During the year the experiment station has erected a brick silo, the first on the island and perhaps the first in the Tropics. (Pl. I. fig. 2.) The object of this is to test the practicability of ensiling grass during the season when it is most plentiful for use in the dry season; also to test the practicability of ensiling the tops of the cane during the grinding season. This material is now largely wasted, but if it could be preserved it would make a very valuable feed that could be utilized when needed. The silo has been filled with the malojillo or Para grass with indications of success. The silage is rather light to pack well and the waste in the preliminary attempt has been greater than it should be. However, it is very probable that this can be overcome. The cane tops from the experimental plats will be ensiled during the coming grinding season.

LIVE STOCK.

As breeding cattle, those of Porto Rico are famous throughout the West Indies as being of superior merit. The exportation of cattle for slaughter has entirely ceased because of the greater domestic consumption of meats and also the necessity of more work animals in the cane fields.

The exportation of other animals has also practically ceased, those that are produced being needed for local use. The increased importation of animals and animal products indicates that many more can be profitably produced for local consumption than at present. With some changes in farm practice, the animal products of Porto Rico can undoubtedly be very greatly increased. Besides grasses there are many waste products which can be utilized for feed, and the work at the experiment station indicates that animais in a climate such as this can be produced with a much less outlay of feed than in the colder countries of the North.

From importations made by the station the indications are that all classes of live stock, including poultry, may be brought to the island from the States with comparative safety. The greatest danger is in the importation of cattle. The great drawback to cattle is the tick. The native cattle are not bothered to any great extent as owing to their short hair the ticks cannot very well hide themselves and are readily picked off by black birds which follow the cattle about the fields. Imported cattle, especially those having long hair, are infested to a much greater extent with ticks. This insect, however, does not appear in such numbers as on cattle in the Southern States. Moreover, as far as observations go, no virulent case, of tick fever has been noted. With the importation of over 50 head of cattle for various parties through the experiment station no losses have occurred from this disease nor apparently have the cattle been ill from it or "off feed." Cases from other parts of the island have been reported as resembling tick fever, but if it occurs it certainly does not possess the virulence, that it does in the States.

American cattle brought to Porto Rico should have better care than the native stock. The Porto Rican cattle can be turned

out to live on very scanty pasture, but with the coarse grasses and hot sun imported cattle must have better treatment. If it is desired to import Northern cattle for improving the herds the breeder is advised under usual circumstances to bring bulls to cross with native stock. These bulls can be stall fed and under such conditions their importation is comparatively safe.

A number of pigs and poultry have been bred and sold to planters in various sections of the island during the year. No unusual difficulties have been found in raising the improved strains. Pigs have been sold at weaning time at \$10 per head and the demand has exceeded the supply. The same may be said regarding the introduction of poultry including turkeys, geese, ducks, and chickens. The foundation has been laid for a dairy herd and a dairy barn has been built.



FIG. 1.—SWORD BEAN (*CANAVALLA* SP.) 5 MONTHS FROM SEEDING.



FIG. 2.—SWORD BEAN GROWING BETWEEN ROWS.



REPORT OF THE HORTICULTURIST.

By M. J. IORNS.

INTRODUCTION.

Fruits ranked fourth in value among the exports of Porto Rico in 1908, and this is destined to be the leading industry, the results already attained being but a fraction of what may be expected in the years to come. Shipments of oranges showed an increase in value from \$84,475 in 1901 to \$630,720 in 1908. As the cultivated groves come into bearing this amount will be greatly augmented from year to year. The increase in pineapple exports has been remarkable for an industry of such recent development. The exports for 1907 were valued at \$128,350 and for 1908 at \$270,982.

As the horticultural work of the station proceeds, the practical problems incidental to a new country are gradually solved, and the work becomes more and more technical, hence the annual report becomes a report of progress rather than a discussion of results obtained, while bulletins or circulars are issued giving the results in detail. During the past year a bulletin on pineapples has been prepared by the writer and his predecessor, Mr. H. C. Henricksen. A circular on the picking and packing of citrus fruits with packing diagrams was also prepared.

In noting the progress of horticulture in Porto Rico, attention must again be called to the great need of trained help in the citrus groves. Many groves are coming into bearing and the available help for the proper handling of the fruit is very inadequate. It is evident that the packing houses must be equipped with all the labor-saving machinery possible. Even with this there will be much loss due to poor handling of fruit until more help can be trained for the work.

A horticultural society has been organized and the work of establishing standards for grading and packing begun and provision made for inspection. Much preliminary work has been done, and it is hoped that by next year the recommendations of the society will be put into practice. The society has also taken steps toward the inspection and control of imported plants, so in that line also results may be expected. During the year a paper called "The Porto Rico Horticultural News" has been established under the auspices of the society. The horticultural department, of the station, by means of this paper, is able to reach the growers with seasonable suggestions gathered from results of work at this and other stations. This is an extremely valuable aid in the advancement of the horticultural work in the island.

INSPECTION TRIPS.

In order to gather data on pineapple and citrus fruit growing the horticulturist was sent by the station on an extended trip to Cuba and Florida. On the way, about a week was spent at various points along the south and west shores of Santo Domingo and Haiti, and at the various ports short trips were made into the surrounding country. Several vegetables and fruits of considerable promise were collected and are now being tried on the station grounds.

In Cuba most of the larger fruit growing sections were visited and considerable data gathered. Special attention was paid to the pineapple sections in Cuba where definite systems of culture and handling of the fruit have been worked out.

The chief point investigated in Florida was the method of handling the fruit. A large number of the more modern and complete packing houses were visited, and many valuable suggestions were received and data collected covering every phase of the fruit growing industry.

Many trips have been taken to the various parts of the island for purposes of demonstration and advice. More of this valuable work should be done as the work of the department permits. This is especially necessary because of the large number of newcomers who are starting fruit plantations.

COOPERATIVE WORK.

In the cooperative work with citrus fruit growers some very interesting data are being obtained. The results cannot be definitely reported until much more work has been done, yet they may be stated tentatively. (1). As indicated in last year's report, the effect of the complete fertilizers as compared with the incomplete is very marked. The dried blood as a source of nitrogen and potassium chlorid as a source of potash gave the greatest amount of vegetative growth. (2). In the bearing groves the legumes seem to be able to supply the major part of the nitrogen necessary, especially if the cover crop is plowed under. (3). The source of the different food elements and their relative proportions materially affect the quality of the fruit. The organic fertilizers gave a coarser fiber and skin, while the unbalanced combinations gave poorly flavored and insipid fruits. (4). The amounts of fertilizer and time of fertilizing affected the time of fruiting.

Such are the chief points indicated by the work thus far. There are a number of other questions such as the effect of the fertilizers on coloring, flavor, juiciness, and other qualities, that are yet too indefinite to be stated. All this makes the subject of fertilizing one of the most vital problems the grower has to solve. The excellent results being obtained from the cooperative experiments have led to the undertaking of a number of other fertilizer experiments both in cooperation with planters and in the station orchards.

THE ORCHARDS.

The work of experimenting with fertilizers, cover crops, and

culture in the orchards has been enlarged to considerable extent during the past year.

In order to have true standards for comparison, a new citrus orchard was planted with the more general varieties of the various citrus fruits. These trees were guaranteed to be true to name by one of the most reliable firms in Florida. This orchard will also be used to test the comparative value of stocks, as part of it is budded on the sour orange, part on the rough lemon, and part on the *Citrus trifoliata*, native seedlings, etc. (Pl. III. fig. 1.)

Pruning and cover crops are beginning to yield results and these are being given to the planters as fast as determined. Already the growing of cover crops has become quite a general practice and the station is pushing the work in every possible way. Systems of alternating cover crops and clean cultivation to check the washing of the soil, to keep the fruit clean, and to increase the soil fertility, are being worked out both on the station grounds and in cooperation with the various planters.

New plantings have been made of avocados, cacao, rubber, and guavas. These are all doing well and afford much more material for experimentation along needed lines.

In the orchard of miscellaneous and introduced fruits, the *Averrhoa carambola*, *Lucuma rivicoa angustifolia*, several of the new Anonas, *Triphasia monophylla*, *Myrtus tomentosos*, and *Spondias axillaris* all produced some fruit during the year. Some of these are very promising and will be propagated for distribution.

The number of improved mangoes has been increased by some twenty new varieties from different parts of the world. From those already in the orchard, over two hundred inarches have been made. Most of these have been used in making permanent wind-breaks about the citrus groves, but a few have been distributed to different parts of the island for trial. Several planters have tried transplanting native mango trees from one to four and even more inches in diameter. When this was done in the rainy season with a ball of earth and the tops were cut back severely, the loss was very small, while the gain in time was several years. Later it is hoped to find some way of working these trees over to commercially valuable varieties.

During the year, experimentation has been continued with the various forms of propagation, but a real commercial method aside from that of inarching still remains to be discovered. This work is of such importance that it will be continued.

While aside from strictly horticultural work, its importance has led the department to do considerable work with the eucalypts. Some thirty species are now on trial and a forest plat has been started for the purpose of studying their behavior. Considerable difficulty was experienced with the seedlings, and in connection with the pathologist, a series of experiments were undertaken to test methods for handling the plants from seed to setting out in the plat, and the troubles have been largely overcome. Much difference is being shown by the various species as to the hardiness and rate of growth of the seedlings. To find some quick growing,

valuable tree for barren hilltops and otherwise waste lands is a very important work.

THE GARDEN.

Following the lines indicated in the last annual report, considerable work has been done in the garden and much data collected.

Many additional points have been brought out regarding the influence of seasons. One of the most peculiar of these is the effect on roselle. When planted from January to May, the plants began to bear very young, in some cases when not more than a foot high. If the fruit was kept gathered before maturing, successive crops were formed on new growth until June or July. Fruit bearing then ceased until the latter part of October, when the main crop was borne, after which the plants usually died. A few plants were induced by heavy fertilization and cultivation to bear one more full crop early in December. If the seed was planted from May to August, no fruit was borne until the main crop was produced in October and November. The result of seeds planted from August to January remains to be determined. As roselle promises to be a valuable crop, more work will be done to further substantiate the above results.

Corn is another crop that shows apparently erratic seasonal variations, which will be made a subject of further study.

The grapes have made exceptional growth and some results have already been determined in the pruning experiments. By two heavy prunings, one in spring and the other in early fall, together with frequent bud pinching, three varieties have been forced into bearing. Other varieties have not been benefited and in some cases the effect seems to be negative. This indicates that much attention must be given to this phase of grape culture. Many cuttings have been distributed by the station and many plants have been imported by various interested parties. It is hoped that in a few years grape culture will be an assured industry.

Work has been continued with the acclimatizing, selecting, and breeding of various vegetables.

It is found that the grafting of the eggplant is not only practical but advisable, especially for home use. The best stock to be used is that of the Berengena cimarrona. In Jamaica they use the "susumber," but it has not thus far proved very successful in Porto Rico. The Berengena cimarrona is found in almost every part of the island and seeds can be readily obtained.

The commercial plantings of muskmelons proved very successful, and much larger plantings are now being prepared for spring shipments.

Chayotes have proved so successful in culinary lines that plantings have been made to test their market value in the States.

In the sandy soils of the north shore and of some portions of the south shore, onions have proved a very profitable crop and the acreage will, no doubt, be increased. The Spanish type is the onion most planted.

PINEAPPLES.

A bulletin on pineapples has been prepared giving the results of the experiments and observations thus far made. New work is under way to further substantiate the less well established conclusions and to clear up some of the points raised by the past work.

Many seedlings are being raised and a number of promising new varieties are being further tested. Six new varieties from Florida have been received and are doing well. Of these two give special promise and will be propagated for trial distribution as fast as possible, but several years must elapse before a large quantity of plants is obtained.

Two new and interesting points are being brought out in the pineapple plantations. The first is that the Red Spanish does not adapt itself well to the heavy soils, while on the other hand the Cabezona seems to prefer such soils, providing the drainage is good. The second point is that some of the sandy soils are too fine grained for good drainage and hence are not suitable for pines.

The effects of different fertilizers on the quality of the fruit, time of fruiting, and the exact fertilizer requirements of the different soil types are being further investigated. The work of breeding a variety of spineless pines by selection is giving some promising results which warrant a continuation of the experiments. In new plantings it has been found advisable to grade the slips according to size and vigor into at least three grades and thus secure more uniformity in the maturing of the fruit.

PLANT INTRODUCTION AND PLANT BREEDING.

Among the plants experimented with during the past year the following have given the best results:

A strain of cucumbers of the White Spine type has been developed that is much more resistant to disease than the ordinary form and bears heavy crops of extra fine fruit. It is not uncommon to find fruits weighing two pounds and more and these have retained their firmness and color for three and four weeks. Seeds of these have been sent to various parties for trial, and the reports thus far received indicate that the strain will prove valuable.

A strain of peanuts has been developed by selection that has an extra fine, large, sweet nut, and in the trial plantings, has yielded at the rate of over 90 bushels to the acre. A few seeds of this strain will soon be ready for distribution and it is hoped that it may become a commercial crop. There is a good home market and besides its value as a nut the plant is a fine soil renovator. It should make a valuable addition to the list of cover crops especially for sandy soils.

Three strains of cowpeas have been developed and samples sent out for trial. One of these bids fair to become a very excellent addition to the already large number of varieties. It differs from the general varieties in having a pod that is of a dark purplish color when ripe. It has made good growth and matured

good crops of seed when all the other varieties tried nearly failed. Besides these three strains, the station is acclimatizing several varieties of cowpeas and sword beans brought by the members of the station staff from Venezuela and some of the islands of the West Indies. Some of these promise to be of special merit.

The strain of "melón de China" mentioned in the last report, has been further developed by crossbreeding with the Rockyford. The resulting type has been propagated and many packages of the seed distributed for testing. The results thus far reported are very favorable. A quite striking result has been obtained by crossing the "melón de China" with the large native form. (Pl. III. fig. 2.)

An interesting point in plant breeding for disease resistance was discovered in this work. A large number of Blinn's best resistant strains of muskmelon were obtained through the kindness of the originator. Trial plantings were made of these and almost without exception the results were negative. In no case did the plants prove more resistant than ordinary ones. Furthermore, native resistant types have in two instances failed almost entirely. As indicated in the last report, there seem to be periodic waves of intense disease ravages and at such times even the strongest plants succumb. Work is being continued along certain lines to determine, if possible, the factors and causes of these periods so that they may be guarded against.

One variety of sweet potato has been found of sufficient merit to be distributed and another crop is almost ready for distribution. Only a few reports of these have been received to date.

Large numbers of trees of Barbados cherry (*Malpighia glabra*), Otaheite gooseberry (*Phyllanthus disticha*), Surinam cherry (*Eugenia mitchellii*), Amatangula (*Carissa arduina*), and Loquat (*Eriobotrya japonica*) are being propagated and distributed as valuable additions to the household orchards. A number of special types of guavas have also been distributed.

It has been proved that root cuttings of the breadfruit can be made, and also that new plants may be obtained with more certainty by a modified form of root cutting. This is done by clearing away the soil and exposing the larger roots for several feet, after which they are severed about two feet from the tree and the ends left exposed. In a short time new plants will start from each cut end. When these are well rooted they may be cut free and transplanted. By this means a number of new plants have been obtained from the seedless breadfruit.

REPORT OF THE ENTOMOLOGIST.

By W. V. TOWER.

Many trips have been made into the fruit, sugar-cane, and coffee districts of the island to investigate various crops which were infested by insects. Those infesting the orange and pineapple have occupied most attention, and a number of new lines of work have been taken up, among them, the fumigation of pineapple slips for the mealy bug, the destruction of ants in pineapples and oranges, also testing the various oil emulsions used by planters, to determine at what stages the purple and white scales were killed by the various strengths and the number of sprayings necessary.

Miscible oils are being tested, many of the formulas proving far superior to the kerosene and crude oil emulsions. A few of the planters are now purchasing ingredients and making these emulsions. From the results in the experimental and demonstration work in various groves, it is recommended that the miscible oils be given a thorough trial in combating the various scales. These oils have been used on the white scale with exceptionally good results. At present the ingredients for miscible oils have to be obtained in the States, but it is expected that soon some of the firms on the island will carry a complete stock.

ORANGE PEST.

The hemispherical scale (*Saissetia hemisphaerica*) can be found only in limited numbers in the groves at present and is not causing any trouble. In the protected groves it is being held in check by fungi.

The purple scale (*Lepidosaphes beckii*) is causing a great deal of trouble in all plantations not protected from the wind and where systematic spraying is not practised. The life history of this scale has been worked out. It takes the female scale from 56 to 65 days to develop and produce her young. The male scale reaches maturity in about 35 to 40 days. From observations made throughout the year it was found that the young appear at no definite period but at all seasons. On account of this continual appearance of young, no definite time for spraying can be followed as with other insects.

Life history. — The eggs are very small and pearly white, and from 30 to 75 in number. The laying continues over a period of 8 to 11 days, the first eggs hatching before the last ones are laid. Some eggs kept in the laboratory did not hatch until the 18th day, while others under the same conditions hatched in 8 days.

The young usually crawl from 12 to 14 hours, after which they insert their beaks into the epidermis of the leaves, branches, trunks, and fruit, and at once develop a covering of white waxy threads. Under this coat or covering they remain for about two weeks, when they form a second covering. At the end of three weeks the male scale can be distinguished from the female. The adult male appears in about five weeks and can be seen with the aid of a glass crawling over the leaves and branches. At this period the females are not fully developed, it requiring seven to nine weeks. At the end of this time they are found with eggs. Individual cases were observed where females developed with full sets of eggs in seven weeks and the eggs commenced to hatch in eight weeks, thus making the life history nine weeks. Other insects under observation at the same time and raised under the same conditions took ten weeks.

The male scale is much smaller than the female, being about 1.5 mm. long and 0.5 mm. wide. Color, reddish-brown to dark-purple.

Adult female scale, dark-purple or reddish-brown; size, 2.5 mm. to 3 mm. long; breadth varying from 1 mm. to 1.5 mm. The female scale looks like a minute oyster shell and for this reason is often called the "oyster shell scale." It should not, however, be confused with the oyster shell scale of the North, as they are quite distinct species.

The purple scale has no definite seasons for producing its young. Crawling young have been found at all seasons of the year here at the station and also in various groves over the island. On account of this irregular appearance it is very difficult to accomplish thorough spraying. The adult scales and eggs are not killed by any of the emulsions heretofore used by the planters. It is now recommended to those who are using kerosene and crude oil emulsions to repeat their spraying in about twenty-one days, thus leaving ample time for the females which escaped the first spraying to deposit their eggs and for these eggs to hatch so that the larvae may be killed by the second application. This method of spraying has been used by a number of planters with very satisfactory results.

The red scale (*Chrysomphalus ficus*) has been sent to the station for determination a number of times during the past year. This insect is much harder to kill than the purple scale, but the young seem to come forth at a definite period. The life history of this insect has been worked out and it was found that the female develops in about the same time as the female of the purple scale. The male scale develops in about 35 days and crawling young generally appear in from 52 to 58 days. The complete life history of this insect will be found in a bulletin to be issued soon.

White scale (*Chionaspis citri*). During the past season this insect appeared in a great number of the older groves, and at the present time is causing the planters a good deal of trouble. The life history of this insect has been worked out, and it requires about the same time to complete its cycle as the purple scale. It does not yield so readily to the sprays as does the purple scale. The first infestation is found on the trunks and large branches.

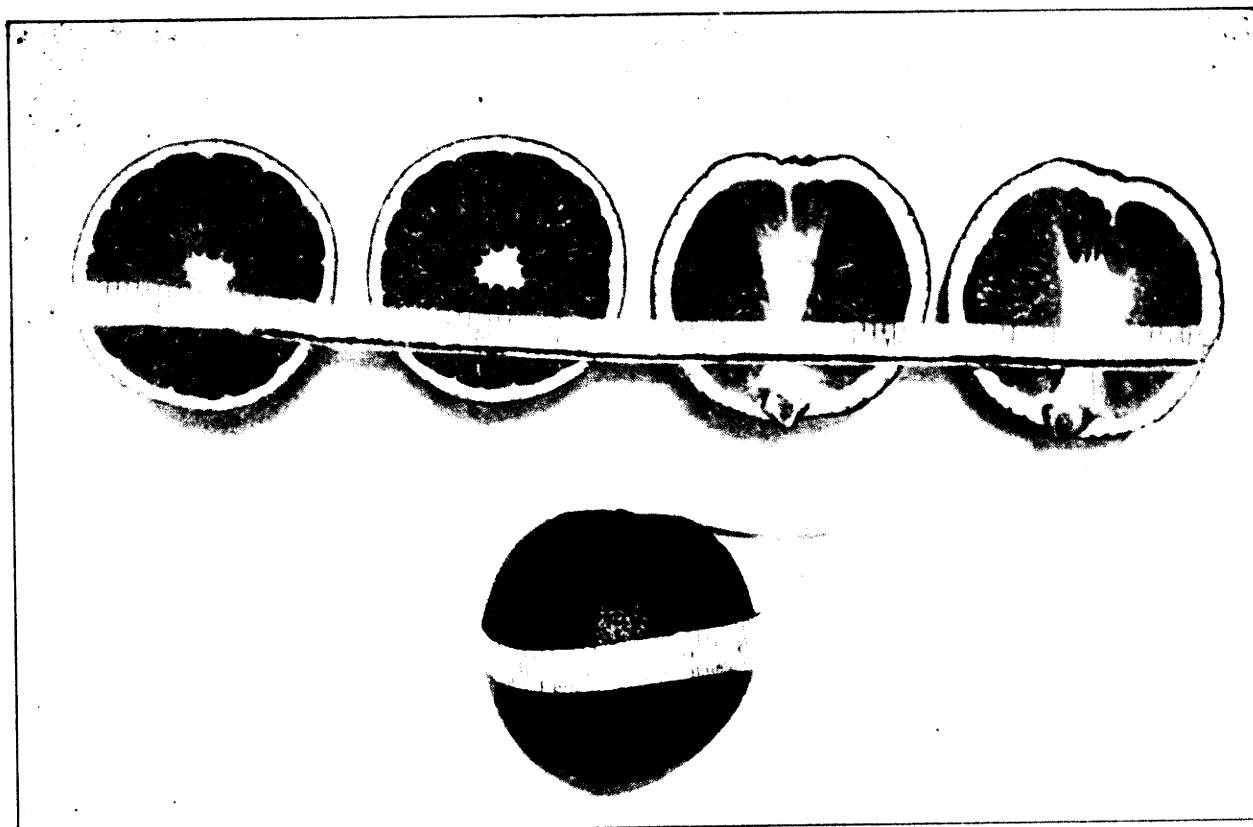


FIG. 1.—A NATIVE SEEDLESS ORANGE

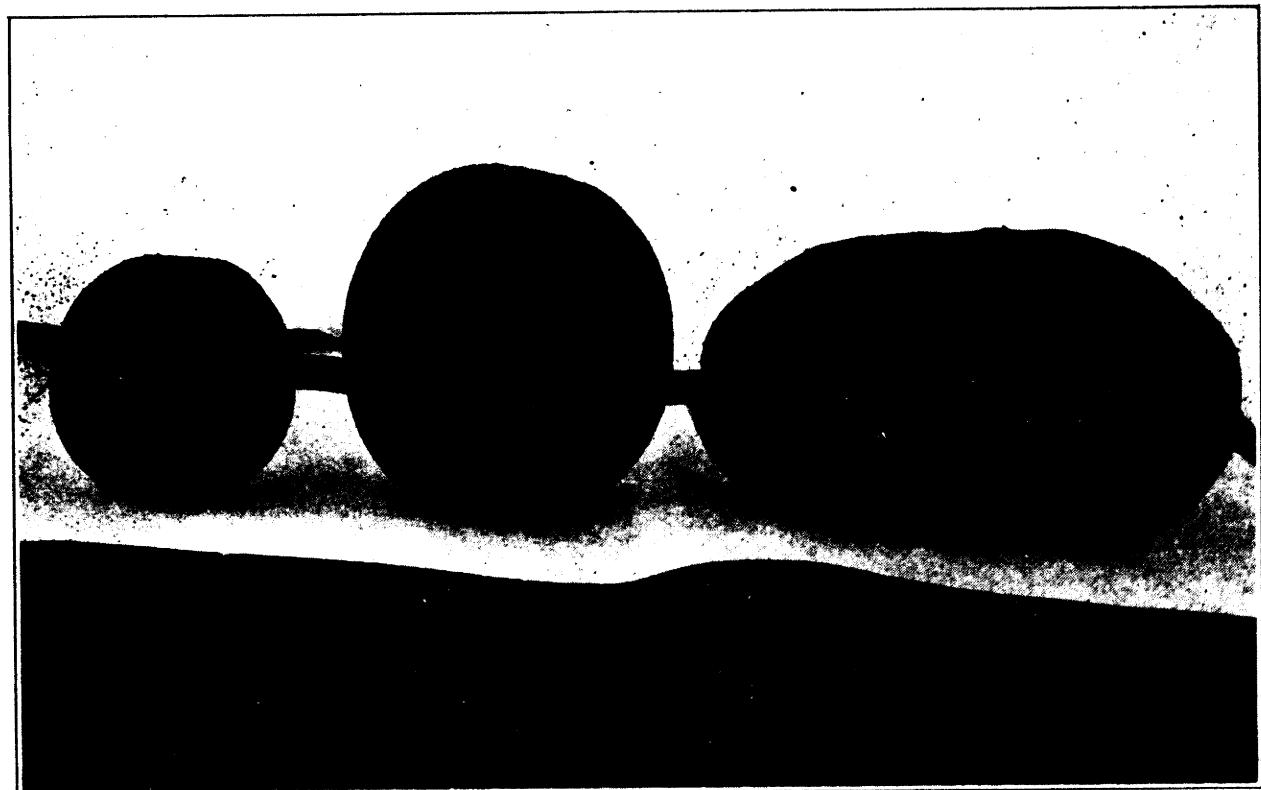


FIG. 2.—BREEDING EXPERIMENT WITH NATIVE MUSKMELONS.
HYBRID IN CENTER.



The young spread more slowly than the purple scale, gradually working up into the tops of the trees. This insect is not preyed upon by the same or as many fungi as work upon the purple scale. There is one fungus, however, which has been found preying upon the white scale, but it operates very slowly.

One spraying with kerosene emulsion, 1 to 5, does not kill the mature female scales with eggs, but the young with their first and second covering are destroyed. The same can be said of crude petroleum emulsions, 1 to 18. It is, therefore, recommended that a second application be made at the end of about three weeks. If there is fruit on the trees a different formula should be used. A kerosene emulsion, 1 to 7 or 8, or crude oil emulsion, 1 part of stock solution to 20 parts of water, should be used, three applications being made at intervals of three weeks. It is also advised that this spraying should be carried on at a time when there is little fruit on the trees, preferably about the time of blossoming. One spray should be applied one week before the blossoms open, the next two sprayings at intervals of three weeks.

It has been the practice among the planters to defer spraying until the trees are in a bad condition.

This is not a wise practice, since many of the trees are coming into bearing and the fruit will surely be covered with scale and will have to be washed. It is well known that washed fruit is not equal to clean, unwashed fruit. Some trees have fruit on them all the year, but it seems best to do systematic spraying at the time when the blossoms set, so that the coming crop will have a clean start. If the scale appears later there are a number of sprays that may be applied to check the scale and not injure the fruit.

The rufous scale (*Pseudaonidia articulatas*,) was first sent to the station during the past year. Since that time it has been found in some of the groves, causing a little trouble. It appears on the under side of the leaves and also on the fruit, but it is very seldom found on the branches. This insect can be held in check by using the same remedies as recommended for the purple scale.

Orange leaf-weevil, (*Diaprepes spengleri*.) This insect was described in the annual report for 1907 as appearing during the latter part of May, but it has since been observed in great numbers during November, there being two broods during the year. A few of these insects can be found at all seasons of the year. The orange is not its only food plant; it has been found feeding on the guava, mango, and the blossoms of the rose.

The "vaquita," a small green beetle, has been causing a good deal of trouble in the orange groves on the northern coast. It is not found on the west coast. It feeds upon the young, tender leaves and also has been reported by a number of planters as scarring the young fruit. Arsenate of lead is being used to combat it, at the rate of 3 to 4 pounds to 50 gallons of water, and the planters are reporting that their fruit is practically free from scars.

"Caculos" and May beetles are causing a great deal of

trouble in the young groves, and one or two cases have been reported where young trees have been defoliated. The caculo is the larva of the May beetle and works on the roots of the tree while the beetle works on the foliage. In the older groves the beetles have much more to feed upon and the damage is not so marked. Many of the planters are hand picking the insects, while others are spraying with arsenate of lead. Where the trees are small, hand picking seems to be more economical than spraying and better results are obtained. Arsenate of lead may be added to Bordeaux mixture or it may be used with kerosene emulsion.

PINEAPPLE INSECTS.

The mealy bug has been found in all the pineapple sections of the island, (Pl. IV. fig. 1) but in the district of Carolina they are causing very little trouble.

During the past season Circular No. 7 was issued on the ants and mealy bugs in pines, and the emulsion recommended has been used by many planters with good results.

Previous to the planting season the slips and suckers of the old plants were found badly infested with the mealy bug. A number of tests were made with kerosene emulsion as a dip, but this did not prove wholly satisfactory as sometimes the mealy bugs would survive the treatment.

Carbon bisulphid was tried for fumigating, but this proved very unsatisfactory. The gas, being heavier than air, sinks to the bottom of the box and the insects in the upper part are not killed. On examining the fumigated plants, it was found that a very high per cent were injured, especially the Cabezonas. The Red Spanish slips and suckers were not hurt, except those which were fumigated for an extended period.

Hydrocyanic acid gas was used for the fumigation of slips and suckers on a small scale with very satisfactory results. On account of the scarcity of plants the tests made did not seem sufficient to thoroughly justify the treatment, so the experiment was continued in cooperation with a planter. Ten thousand slips were offered for the tests and were run through the fumigating box with various strengths of gas. Some were planted immediately and others after having been left in the shade for a while. After these had been in the ground three weeks 40,000 more plants were fumigated. The growth of the slips seemed to be retarded a little, especially in the first 10,000 but this was not wholly the effect of the fumigation, as the slips were planted in a very dry period. The group of 40,000 were planted during the wet season and started up much more quickly. Of the 50,000 plants fumigated a very small percentage was lost and hardly any were seriously injured. The mealy bugs in all stages were killed with one ounce of potassium cyanid for every 100 cubic feet.

A number of plants were taken from the box and immediately placed in the sun light; the leaves at once became yellowish white and in a few weeks dried up. The hearts of these plants and lower parts of the leaves were not injured and in a few weeks

were sending out roots, although they were not planted. This discoloration will not appear if the plants are left in the shade at least 24 hours after fumigation.

It is not advisable to fumigate wet plants, as the moisture which collects between the leaves forms an envelop that prevents the gas from passing down to where the insects are working.

For this fumigation a box containing 75 cubic feet was used and proved to be a very convenient size. Plants for the fumigation tests were gathered in sacks in the fields and brought to the box and fumigated without being emptied. After the fumigation the plants were removed from the sacks, sorted, and placed in bins according to size. The same results were obtained with plants which were first stripped and then fumigated. Where a great many thousand are to be fumigated it is more convenient to run them through before stripping, as the plants can be sorted later as needed, while if they are stripped first they must be planted very soon after the fumigation or they will spoil. It is not always convenient to plant at once, so it is recommended to fumigate, size, and strip, just before planting.

COFFEE INSECTS.

A coffee weevil has been found the past season in a number of the plantations around Ponce, and in some districts the planters complained that it did a great deal of damage. Some of the trees attacked were defoliated but soon put out new leaves and shortly appeared as if they had recovered. A study of this insect will be made next season.

The coffee stem borer was sent to the station for identification. At present it is not causing any serious trouble. Some damage is reported in one or two localities. This borer has other host plants, among them are the orange, citron, rose apple, and sweet almond. To destroy the insects run a flexible wire in the holes.

B E E S.

During July, 1908, the station purchased five nuclei of Italian bees in the States. They arrived in very good condition and were at once transferred to 10 frame hives. From time to time additional frames were added to the hives and by the first of October the bees began storing honey. Honey boards were put on with supers and by December 13 they were full. Thus in five months each nucleus had developed sufficient bees to raise brood and to develop 17 frames of comb, 10 of which were filled with honey.

The honey extracted has been of two grades; that collected from the general bloom of flowers has been classed as amber, and that which comes from the guamá, white. This tree is used extensively in coffee plantations for shade, and honey from it is said to compare very favorably with basswood or linden honey. It is a heavy honey plant and blooms three or four times during the year. Other plants or trees which produce heavy bloom or honey flows are the coffee, having from three to five short blossomings; the mango, one blossoming; the orange and grape-

fruit, generally two blooms; and the royal palm and cocoanut, several blooms.

The bees have not gathered honeydew up to the present time and it does not seem probable that they will as long as there are plenty of flowers. If at any time they should collect it in large quantities, it would be better to feed it back to them and let them make wax.

Most of the bee keepers are located in the interior, although there are a few apiaries along the coast in the lower foothills. The interior part of the island is the best locality, as the blossoming is more abundant. Any part of the island, however, is adapted to bee raising, except the south coast, where it is very dry and where at certain times of the year it would be necessary to feed the bees.

In the coffee sections where bees are kept it is said that the coffee is always much heavier than in sections where the pollination is carried on by the wind. This has been noted especially in seasons of continual rainfall at time of blossoming. During heavy rains the pollen cannot be blown from blossom to blossom, which results in scanty setting of fruit. Under such conditions bees are very valuable, as they carry pollen whether the weather is wet or dry.

In Brazil it is reported that each coffee plantation has its bees and when the place is sold they are considered a fixed part of the property.

Another industry which seems especially adapted to Porto Rico is the raising of early queens for the Northern market. Queens can be raised here at any time of the year as we have no season when the bees do not work.

MISCELLANEOUS NOTES.

The guavas have been attacked during the past season by the mealy bug. A number of sprays were applied and it was found that kerosene emulsion, 1 part of stock solution to 6 or 7 of water, was very effective. These insects probably make the punctures on the young fruit through which the fungus enters that produces the mummy disease.

Great numbers of thrips have been observed on the underside of mango leaves. Their punctures probably allow the entrance of spores which produce anthracnose.

The following formula has proved very effective for destroying ants' nests: 1 pint of crude carbolic acid (100 per cent crude), $\frac{1}{2}$ pound of whale oil or common laundry soap, and 1 quart of water.

Dissolve the soap in one quart of boiling water and add the carbolic acid and sufficient water to make a stock emulsion of two quarts. Use one pint of stock to 6 gallons of water. One spraying of ant hills is not sufficient, as many of the ants are away in the field at the time of the first spraying. These, upon finding their home destroyed, build a new nest close to the destroyed old one. A second spraying should be applied the next day when the ants are preparing their new home.

REPORT OF THE CHEMIST.

By P. L. GILE.

INTRODUCTION.

The chemical work the past year has been somewhat miscellaneous in character, as an attempt has been made to accomplish something besides the routine analytical work. The first part of the year was spent in fitting up the laboratory, installing a gas machine and other apparatus. Along with the analysis of the samples sent to the station and the chemical work done for the other departments, some research has been conducted on the catalase content of soils. The results of this investigation will be published separately.

The analytical work can be summarized as follows :

- 23 complete analyses of soils.
- 20 analyses of soils for one or two constituents only.
 - 4 " " limestones.
 - 16 " " bat guanos.
 - 6 " " commercial fertilizers.
 - 2 " " fertilizing materials.
 - 2 " " ores.
- 1 mineral analysis of water.
- 19 analyses of citrus fruits for fiber and acidity.
- 21 " " sugar canes.

SOILS.

A complete chemical analysis has been made of 23 soil samples, and an equal number have been examined in a general way for acidity, lack of humus, etc. While the idea has been to secure a knowledge of the chemical composition of the various soil types of the island, it has not been possible nor advisable to make a complete analysis of all the soil samples sent to the station inasmuch as the chemical analysis of a soil is a long and expensive piece of work. Such analyses have only been made when the soils have presented unusual features.

Many of the soils which have been studied, particularly the heavy clay cane soils, have proved to be acid. For such soils liming has been recommended, with the idea of neutralizing the acidity and at the same time of improving the physical condition. A plat experiment was started at the station to observe the effect of liming a soil of this character. Unfortunately the cane was blown down by a high wind before it reached maturity, so that no quantitative data could be obtained. The beneficial effect of liming, however, was quite apparent.

Several samples of very unproductive soils were received from the vicinity of Ponce and Santa Rita. On analysis they

were found to contain an abundance of humus and plant food, but to have a strong alkaline reaction. In this case a heavy application of gypsum was recommended, as Hilgard has found this beneficial in treating similar soils of California. The beneficial action of gypsum lies in the fact that it reacts with the alkaline carbonates of the soil, changing them into the less injurious sulphates. The results of this treatment will not be known until next year. Such alkaline soils occur only in spots and to no great extent on the island.

Field experiments have been made on the behavior of lime and gypsum on Porto Rican soils and also on the stimulating effect of carbon bisulphid on sugar cane and pineapples. The results of the experiment on the stimulation of pineapples by treatment of the soil with bisulphid have been such as to warrant the repetition of the experiments on a larger scale the coming year.

BAT GUANOS.

Bat guanos are found in many caves on the island and often in considerable quantity. The character of these deposits varies greatly, depending on the age and amount of leaching that they have been subjected to. Some samples that have been examined have suffered practically no decomposition, while others are so completely decomposed that they contain almost no trace of organic matter. These latter appear like a reasonably pure limestone or sometimes like an ordinary ferruginous soil, the only evidence of the former accumulation of organic matter being the high phosphoric acid content.

Below are given the analyses of sixteen samples of guanos received from various parts of the island.

ANALYSES OF PORTO RICAN BAT GUANOS.

Sample No.	Moisture Per cent	Volatile Matter Per cent	Ash Per cent	Nitrogen Per cent	Phosphoric Acid Per cent	Potash Per cent
27	8.66	16.96	74.38	.88	12.13	.29
28	14.33	53.61	32.06	5.58	6.90	.24
29	7.80	37.32	54.88	.51	.75	.09
17	7.67	36.79	55.54	1.99	8.49	.55
36	4.35	10.63	85.02	.09	2.88	.23
40	2.86	24.34	72.80	.09	8.84	.79
41	5.85	26.77	67.38	1.92	14.11	1.90
42	13.80	14.52	71.68	.76	12.44	.41
43	6.66	10.48	82.86	.12	16.65	.71
44	8.63	12.72	78.65	.17	21.42	1.47
60	8.34	15.68	75.98	.20	17.84	...
61	7.84	27.22	64.94	.30	3.33	.05
62	2.72	27.34	69.94	.10	15.61	...
64	16.57	10.29	73.14	1.12	2.85	.98
65	17.43	71.98	10.59	9.27	4.31	.77
72	3.77	27.65	68.58	.04	2.63	...

The volatile matter in the above table is not to be taken as a true indication of the amount of organic matter contained in the guano since in many cases the volatile matter consists largely of CO_2 evolved from the carbonates present.

Only two of the samples, Nos. 28 and 65, contain appreciable amounts of nitrogen, and in these two cases the nitrogen is largely present in an unavailable form. From a microscopical examination it is evident that the samples are composed of fragments of insects that have suffered no decomposition. The chief chemical constituent of these fragments is chitin, a substance containing about 7 per cent of nitrogen. As chitin is exceedingly resistant to decay, the nitrogen that it contains must be regarded as unavailable. Experiments at the University of Tokyo have shown guanos whose nitrogen is all present in the form of chitin to be practically worthless.

Sample No. 65, however, contains beside the nitrogen present in chitin at least 4 per cent of nitrogen in another form, probably in urea and uric acid, which is readily available.

It can be seen that none of the samples examined contain much potash, many of them being but little richer in this element than the ordinary soil. In fact, it is very rarely that cave deposits of this kind contain as much as 2 per cent potash.

From the guanos that have been studied thus far it appears that most of them have little value as nitrogenous or potash fertilizers, but that they do contain sufficient phosphoric acid to make them valuable as phosphatic fertilizers.

The exact value of the phosphoric acid contained in the cave deposits as compared with other forms of phosphoric acid is not known. In most cases it is probably much less than that of the commercial forms. An attempt will be made to ascertain this the coming year.

Some of the cave deposits contain considerable lime which gives them an added value, particularly for acid soils. There are also many cave deposits with a considerable iron content. These are less valuable than those containing lime, since the phosphoric acid in this case is largely present in the insoluble form of ferric phosphate.

FERTILIZERS.

Since there is no law in force on the island providing for the inspection and certification of commercial fertilizers, very few samples have been analyzed this year. But from the few analyses that have been made and from the reports of the planters, who are using commercial fertilizers quite extensively, it is evident that there is a crying need for such a law protecting the buyer.

Cyanamid has been tested for deterioration on storage under the conditions existing in Porto Rico. This is a high grade nitrogen fertilizer formed from atmospheric nitrogen, coal, and limestone.

A ton of cyanamid was received at the station the first of January and on May 1, two samples of it were taken, one representative of all in the bin and one from the superficial layer only.

These samples were not analized until August 8. As the sample jars were not absolutely air tight there was probably some loss of nitrogen during the three months pending analysis, but this loss could not have been so great as the cyanamid would have suffered under ordinary conditions of storage. Analysis of the sample representative of the whole lot gave the nitrogen content as only 13.05 per cent instead of the usual 19 per cent or more. The sample of the superficial layer ran lower still, yielding only 9.48 per cent nitrogen.

The cyanamid stored in the bin was again sampled on December 10. As before a sample was taken of the superficial layer and one representing the whole amount. The sample of the whole contained 10.89 per cent nitrogen and that of the superficial layer only 9.44 per cent.

It is very evident that cyanamid deteriorates rapidly in this climate where the temperature and humidity are uniformly high. It is probable that the cyanamid undergoes a decomposition during storage similar to that which is supposed to take place more rapidly in the soil. At all events the final product of the decomposition and the form in which the nitrogen escapes is ammonia.

The evolution of ammonia takes place to such an extent that it can readily be smelled after a portion of cyanamid has been confined for a time; and moist litmus is quickly turned blue.



FIG. 1.—MEALY BUG ON PINEAPPLE SLIPS.

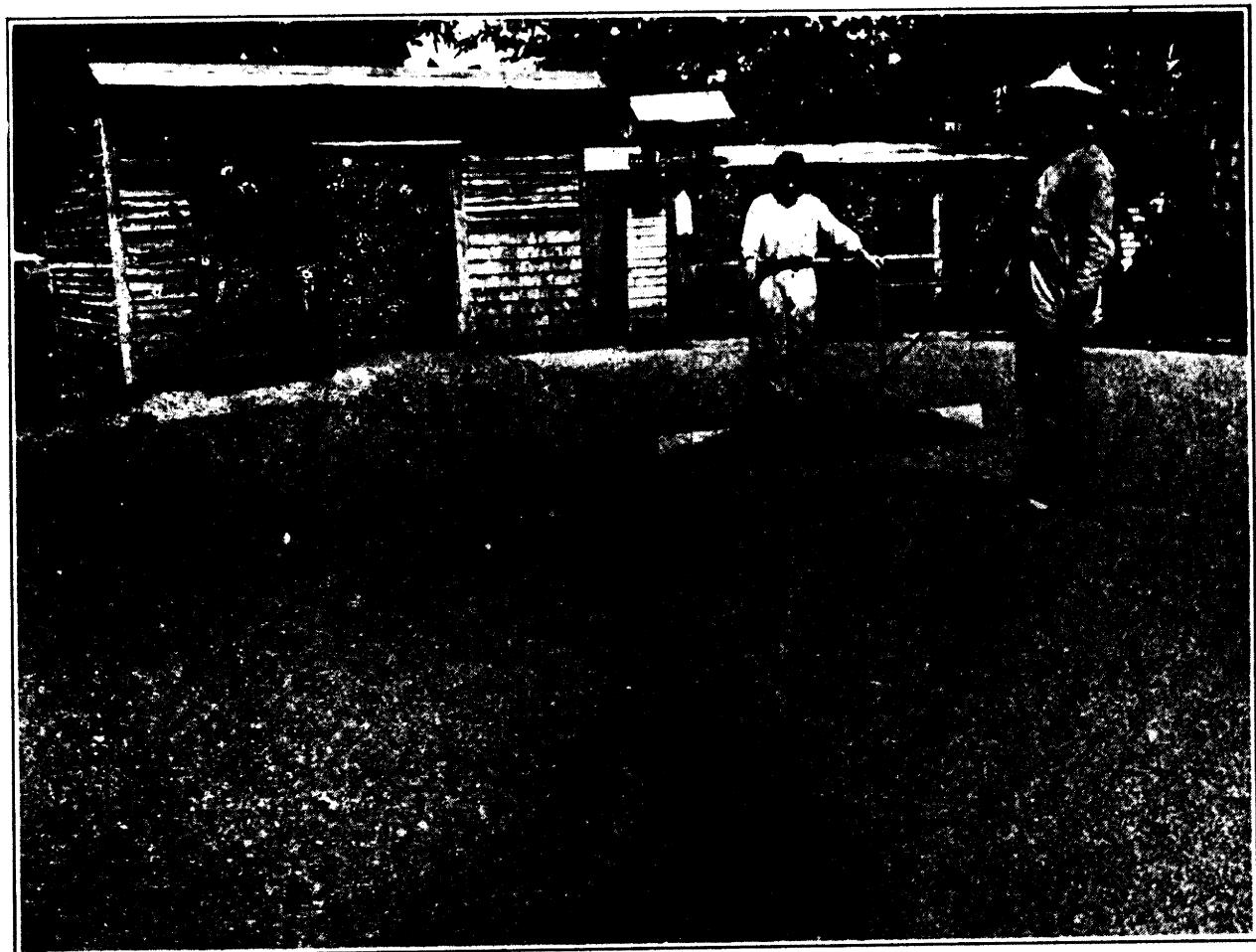


FIG. 2.—SPREADING COFFEE TO DRY ON PLAZA.



REPORT OF THE COFFEE EXPERT.

By J. W. VAN LEENHOFF.

Storms during the last months of 1906 and in March, 1907, very dry weather during April, 1907, and abnormal heavy rainfall during May, 1907, followed by hail in September at the beginning of the harvest, were so many factors that influenced in making the coffee crop less abundant than last year's.

The bananas planted last year as provisional wind-breaks have now grown up and formed an efficient protection for the young coffee during the strong winds in the beginning of 1908. These provisional wind-breaks seem also to have greatly benefited the growth of the young permanent wind-breaks planted between the rows.

Of the insect pests, weevils have done much damage on the substation and surrounding plantations, especially at altitudes of about 2000 feet above sea level and over, mainly in the young coffee, several patches of which had the leaves and green parts of the twigs entirely gnawed off, and even young green berries were destroyed to some extent.

Borers are doing a great deal of harm to the guava shade trees in several important districts, in some cases entirely destroying them. During a visit to the Utuado and Coamo coffee districts hundreds of dead or dying shade trees were seen. In these same districts the coffee leaf blight is very apparent as shown by the numerous brown leaves hanging by shreds.

Coffee leaf miners, although everywhere abundant, seem to be kept in check by their parasite.

IMPROVEMENT OF AN OLD COFFEE GROVE.

The yield this year, from a renovated coffee grove, was only 2,472 pounds as against 4,349 pounds in 1906-07. The blossoming of May, 1908, indicates, however, that the next crop will be much larger.

All former experiments were continued during the year.

COST OF GATHERING AND PREPARING 100 POUNDS OF COFFEE READY FOR MARKET.

Cost of picking.....	\$ 1.40
" " field labor.....	2 55
Preparation for market75
Transportation from field.....	.20
" plantation to Ponce.....	37½
Total cost per 100 pounds..	\$ 5.27½
Average price obtained per 100 pounds.....	\$ 11.23

EXPERIMENTS WITH NEW PLANTINGS.

COST OF PLANTING COFFEE IN PORTO RICO.

Expenses per acre for fourth year, 1907-08	
4 weedings, at \$2	\$ 8.00
1 hoeing between rows	4.44
Total expenses fourth year.....	\$ 12.44

There was gathered in the 4th year 214 lbs. coffee produced by 2,416 young trees from 2 to 4 years old, and covering about 3 acres of land.

Per acre 71 lbs. coffee worth, at \$11.23 per 100 lbs. \$ 7.97
Less cost of picking, preparing and transportation 2.73
Net cost per acre of coffee four years \$91.56

The foreign coffees are doing very well and several are loaded with fruit.

Coffea robusta, a coffee variety which according to information is now attracting much attention in Java, is represented at the substation by 3 specimens.

One was top grafted on Porto Rican coffee and is doing finely, the graft having several fruits on it. One was top grafted on Maragogype and is also doing finely although yet without fruit. One was left in its original condition and is now a splendid young tree, which blossomed heavily this year, but hardly any fruit has set. Different other grafts with *Coffea liberica* as stock are doing finely and are bearing fruit.

The fields planted exclusively with Porto Rican coffee have improved considerably since the provisional wind-breaks have grown up, and are loaded with fruit.

Altogether the experiments have done well and results should begin to show at the end of this harvest.

The native method of drying coffee is shown in figure 2 of Plate IV.

REPORT OF THE PLANT PATHOLOGIST.

By G. L. FAWCETT.

In beginning work at this station it was found desirable to obtain some knowledge as to the general conditions of the island with regard to plant diseases. In this study some of the agriculturally more important sections were visited and observations made on the presence and distribution of such diseases. More time was given to this because of the laboratory side of the work being hindered by a temporary lack of suitable equipment. Some of the results of this study are given in this report.

Among citrus fruits comparatively little disease was observed. The foot-rot is not uncommon in wet, poorly drained lands, but this is capable of control. Scab is quite common especially in young lemon trees. No cases of withertip were noted, nor of the physiological blight disease, so destructive in some other citrus growing regions; but as most of the budded groves are young, and only mature, fully bearing trees are subject to attack, its presence is hardly to be expected. The die-back due to overfeeding with organic nitrogen is not found in the citrus trees of Porto Rico at the present time; this may be because excessive applications of manures rich in such nitrogen have not been made.

The pineapple has one conspicuous disease characterized by the appearance of white spots on the leaves. This is caused in many cases at least by the entrance of organisms through wounds such as the punctures made by sucking insects. At first the spots are small and brown. Gradually they enlarge, the epidermis sinks, the interior tissue is destroyed, and the white bleached appearance is taken on. It is in no sense a serious disease although common under excessively moist conditions. Another disease of this fruit now being studied is characterized by a decay of the root system. This has been observed up to this time only in fields with stiff, impermeable soil. It is apparently favored by excessive rainfall. Not only the pineapple but many other fruits grown in soil of this nature are affected with root rot. The obvious remedy of not growing the plants on such soils cannot be resorted to for the reason that there are sections where comparatively large areas of clay land are found.

The sugar cane in Porto Rico is largely free from fungus diseases, and only in some places on the east coast, where the rainfall has been excessive, are they to be found in any abundance. The rind disease is much in evidence there, even where the plants are free from mealy bugs or other insects. Usually this disease follows the attacks of such insects. The canes in one field were found to be suffering much from the attacks of a

soil fungus. The fruits of an agaric-like fungus appeared in abundance on some of the dead stalks, but whether these are the fruits of the cane destroying fungus, is not yet determined. No other fruiting bodies were found. Slight attacks of the root disease were noticeable in many comparatively healthy fields in other parts of the island. The rind disease was also present to some extent in many of the fields. That both diseases are not more common is due in part to cultural methods now employed.

REPORT OF THE ASSISTANT ANIMAL HUSBANDMAN.

By E. G. REIZMAN.

In the quality of live stock Porto Rico stands at the head of the West Indian islands. Formerly, large numbers were exported principally to the surrounding islands, but this exportation has gradually diminished in value.

The following table shows the number and value of live stock exported to foreign countries:

EXPORTS OF PORTO RICAN LIVESTOCK.

YEAR.	HORSES AND MULES		CATTLE.	
	Number.	Value.	Number.	Value.
1901	4,143	\$ 118,694	12,829	\$ 457,938
1902	2,406	64,930	13,357	354,065
1903	1,540	32,114	11,273	291,650
1904	4,187	101,405	13,110	316,131
1905	2,574	73,917	8,185	206,655
1906	767	22,329	7,161	150,679
1907	104	6,586	215	4,071
1908	115	17,270	11	600

HORSES.

The station has in previous reports emphasized the necessity of increasing the size of the native horses and mules. The native horses are small but possess much stamina. They are practically all of a saddle type and go very easy gaits, the most common of which is a racking pace; some of them, however, possess more stylish action; one gait is especially attractive, a fast rack with the high fore-feet action of a hackney. Horses possessing this gait are in demand and command high prices.

Some very good results have been obtained by several breeders in crossing imported saddle gaited and trotting bred stallions on native mares, with material increase in size.

Practically no horses are used for working in the fields, as they average too low in weight for that purpose, the greater number being probably under 800 pounds. Many horses are unsound. A very common defect easily noticeable is a knee-sprung condition. It results probably from being ridden too young and general hard usage on the macadam roads. Native mules are

also below the size to be used profitably for working in the fields. They are used mostly for pack animals. In hardiness they are the equal of native horses. By breeding American jacks to crossbred mares of good size some mules, now about yearlings, have been obtained which promise to be of good size.

The keep of horses and mules costs much less at the experiment station than in the States. Two horses receive 2 pounds each of oats per day, and two other smaller ones receive only 1 pound per day with Para grass for roughness. These horses, however, receive very little exercise. The mules, which are worked constantly on the road and in the fields, receive 8 pounds of oats daily with Para grass. This is less than one-third the amount of grain that would be fed to mules and horses of the same size in the States. Silage from Para grass has also been fed to the mules. When fed with about 1 liter of cane molasses diluted in water and sprinkled throughout they ate it with relish, but when molasses was not mixed with it they apparently cared little for it.

CATTLE.

The characteristics and merits of Porto Rican cattle have been sufficiently described in previous reports. The aim of the station has so far consisted in encouraging improvement in earlier maturity and a larger milk production. Unfortunately, the station has not been in a position to experiment along this line, but it is hoped that this can be undertaken in the near future, as large quantities of dairy products are at present imported and milk retails at exceptionally high prices. Improvement in more sanitary production and handling of milk is also desirable. Doubtless great improvement can be made by the use of good bulls from approved dairy breeds of cattle, but it would perhaps be better to introduce sires of such blood which more nearly resemble the native stock, as for example the Guernsey or Jersey. Some crossbred calves from Hereford bulls on native cows have been seen which resemble the Hereford in all characteristics, and as near as can be judged in young calves they promise to develop good beef types. One of the characteristics that crossbred animals seem to inherit from native stock is a very short, smooth coat in which it is more difficult for ticks to live.

The eradication of ticks from Porto Rico is an exceedingly difficult problem as they are constantly carried from one field to another by the work oxen. Spraying with a kerosene emulsion consisting of two gallons crude kerosene, one gallon of water and one-half pound of soap appears to be insufficient in killing ticks when applied with a spray pump. Live adult ticks which hatched larval ticks have been picked from a Shorthorn cow at this station one and two days after spraying.

Silage from Para grass mixed with a small portion of cowpeas has been fed to the cattle. The results were very unsatisfactory when they had access to green grass. They seemed to care little for it unless mixed with molasses and when no grass was fed, as was the case with the mules,

SHEEP.

According to the census of 1899 the island possessed only 3,363 sheep. The sheep seen in this neighborhood and some seen in the hills between Ponce and Coamo, which doubtless represent fairly well those found in other parts, are large coarse animals of poor mutton type with a patchy, inferior fleece that would hardly shear 2 pounds. There is no reason why the cooler inland hills could not grow as good wool sheep, when properly handled, as the Merinos found in Spain. The continuous warm climate along the coast would probably be adverse to such an undertaking.

During the past year the station has obtained 5 ewes and 1 ram of African woolless sheep with the view to encourage the production of mutton, which is in great demand. They are a hardy breed, make good "rustlers," and should be admirably suited to native uses. They require comparatively little attention. Up to the present they have not been troubled with insect pests or parasites and no indication of foot rot has been noticed during the rainy period, as they are kept in a well drained paddock with access to a dry shed.

GOATS.

Goats are much more numerous on the island than sheep. At present they undoubtedly furnish a large part of the meat that is sold for mutton as well as the milk for family use of the poorer classes. If any milch goats have ever been brought to the island they are now very much mixed with native stock. Canary island goats, which are good yielders, are said to have been brought in by one breeder, but they have not been kept pure. Native goats do not yield over 2 liters of milk daily. Owing to lack of system in breeding, the stock has very much deteriorated and it would therefore seem advisable to bring in some animals of a breed that would be adapted to this climate and give better results.

HOGS.

Berkshires are the only breed kept by this station at present. They keep in good health, are thrifty and vigorous and appear to do well on the native grasses. They are also fed shorts, corn-meal, and tankage in the ratio of about four parts shorts, two of cornmeal, and one of tankage. A moderate amount of tankage is especially desirable for growing pigs, as no dairy by-products are available. Brood sows with pigs are given much range on which to forage with access to shade and fresh water.

NOTES ON THE SOILS OF PORTO RICO.

By O. LOEW.

The luxuriant tropical vegetation observed in various parts of Porto Rico points to a favorable condition of the climate as well as of the soil. Nevertheless there exist in some of the cultivated soils some defects as investigations carried on at the experiment station have shown. Some were found to be so stiff as to obstruct growth and respiration of roots, some showed an acid and others an alkaline reaction, again others were found to contain an unhealthy excess of magnesia over lime. Nematodes were also found in tobacco seed beds as well as upon the roots of the coffee tree. Sometimes two or three unfavorable conditions combine in one place. In fact in one locality (Buena-ventura) a cane plantation was abandoned on account of decrease of returns.

In regard to the sufficiency of mineral nutrients it should be remembered that the same data can not be applied alike for northern and tropical lands. Even in spite of great deficiency of potash and phosphoric acid in soils, coffee, cacao and cotton can yield a fair growth in the Tropics, as Hébert^a has reported from central and western Africa.

In loose, open soils the required percentage of the nutrients may, of course, be lower than in close soils, since in porous soils the roots can easily spread in every direction in search of the available necessary minerals. Detmer and Immendorff^b reported in the best soils of Java a high content of available potash (0.24 per cent), phosphoric acid (0.16 per cent), and nitrogen (0.56 per cent). The soils of Porto Rico thus far analyzed at this station make a fine showing in this regard. In 6 samples of soil from cane land the amount of phosphoric acid was found to vary between 0.14 and 0.26 per cent, and in 16 samples from tobacco plantations there was only in 4 cases less than 0.1 per cent.^c As to potash the former group of 6 soils showed 0.17 to 0.57 per cent, while 12 of the 16 samples of tobacco soils showed 0.11 to 0.47 per cent. Phosphatic and potassic fertilizers can, therefore, be dispensed with on most of these soils. However, small doses may be applied to the young plants when a rapid start is desired. The nitrogen content of the soil samples

^a Quinz. Colon., 11 (1907), No. 4, p. 131.

^b Botanische und landwirtschaftliche Studien auf Java. Jena, 1907, pp. 26-36.

^c As to phosphoric acid, a special determination will be required to decide how much of it is firmly fixed in the humus in organic combination

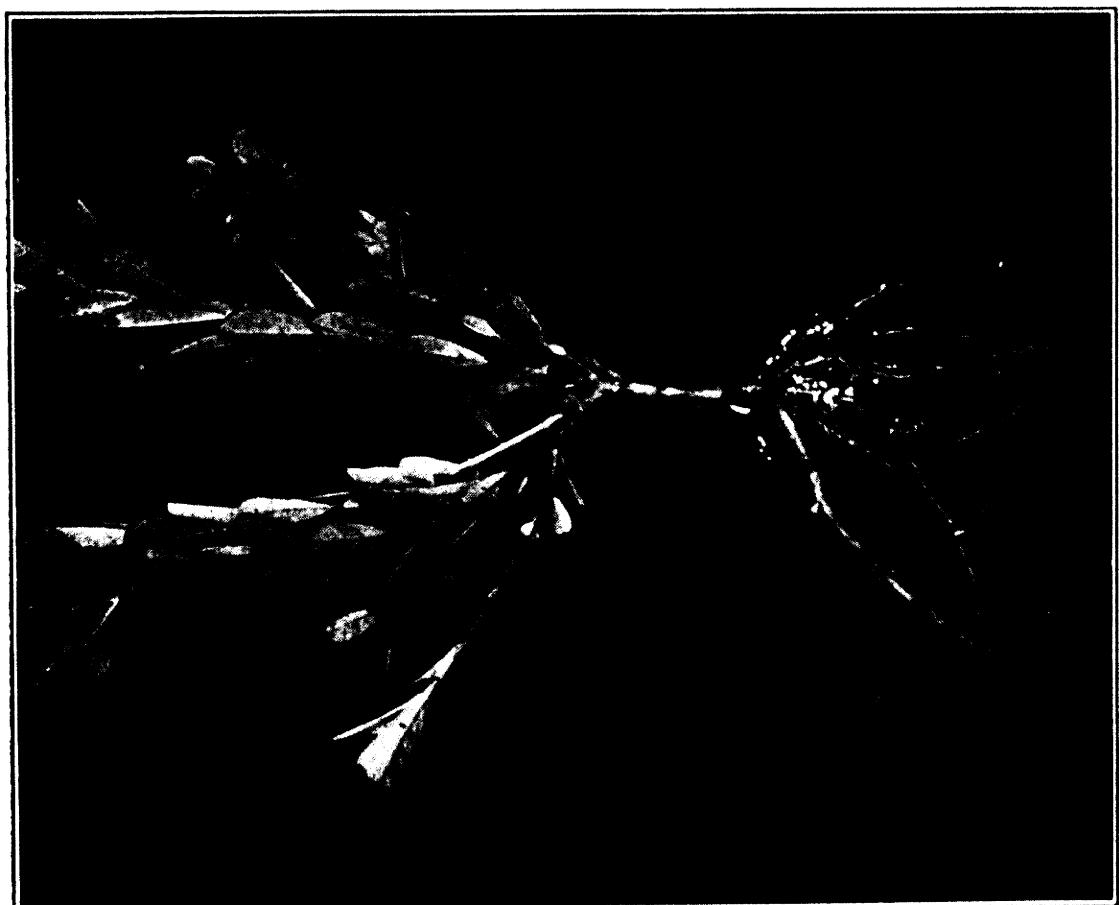


FIG. 1.—*CROTALARIA RETUSA*,
A NATIVE LEGUMINOUS PLANT.

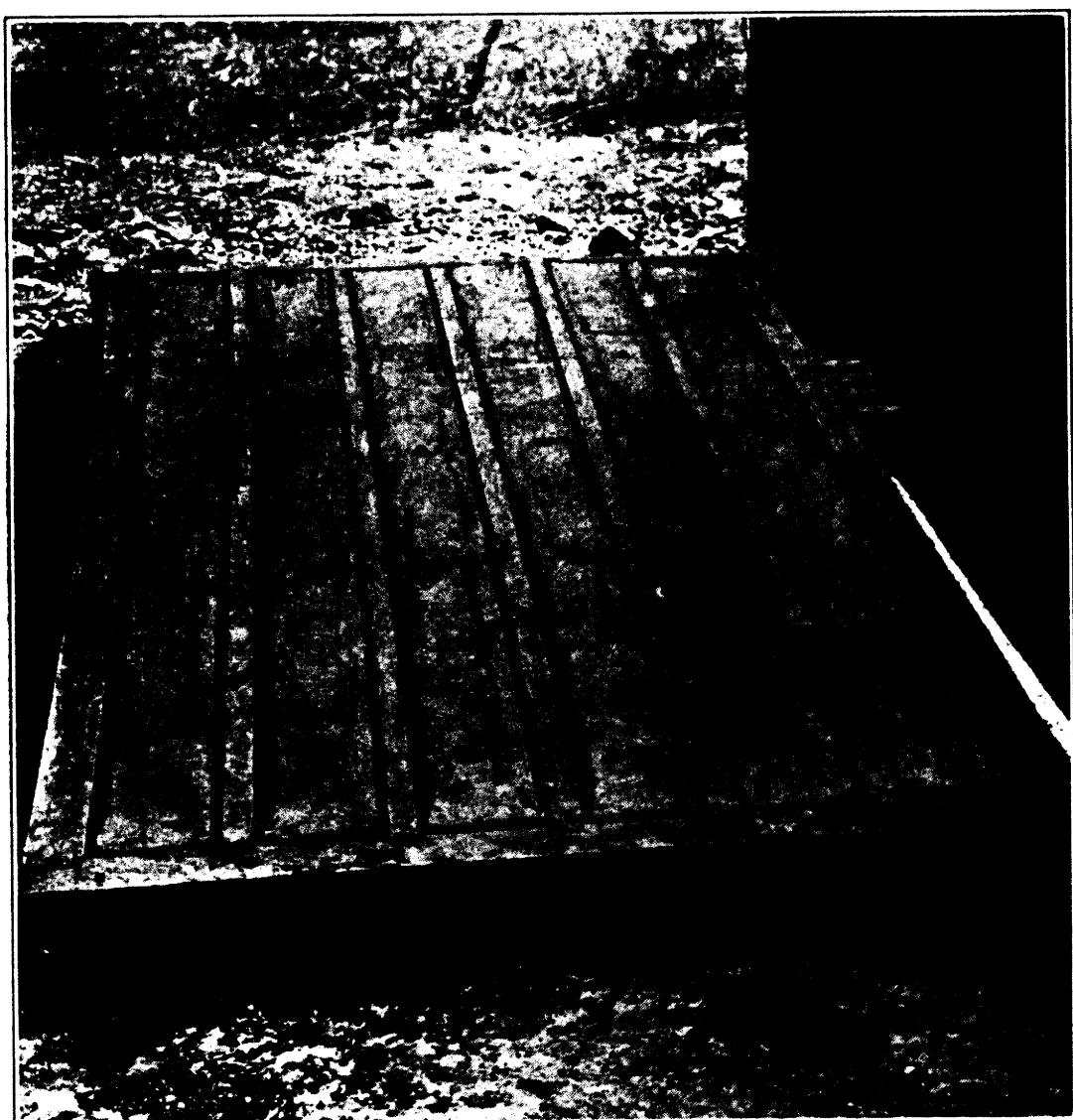


FIG. 2.—MOLDS FOR CONSTRUCTING CEMENT FENCE POSTS.

from the cane land varied from 0.12 to 0.21 per cent, and in the samples from the tobacco land from 0.09 to 0.63 per cent. However, how much of this would be directly available can not be easily determined.

Opinions are still divided as to the minimum percentage of lime required for good returns. Some hold that 0.2 per cent lime in tropical countries is insufficient but this depends not only upon the close or open nature of the soil, but also upon the relative amount of magnesia present. The higher the magnesia content, the higher must be the lime content also. In regard to lime and magnesia the percentages vary considerably in the soils of Porto Rico.

In the western part of Porto Rico three types of soil may be recognized: (1) Very loose sandy soil containing sometimes fragments of marine shells, extending along the sea beach and bearing chiefly cocoanut palms. (2) A dark gray or black and very stiff clayey soil, extending from the base of the central mountain ranges to the sandy belt along the coast. It occupies lowlands and valleys and serves chiefly for cane plantations. (3) A loamy soil of intense red color, covering the hills and the mountain sides to a great extent. It is the product of disintegration of shale and a certain kind of trachyte and serves chiefly for culture of oranges, coffee, cacao, and bananas. This soil is not a so-called laterite soil,^a observed frequently on the coast of tropical countries with moist climate.^b

A detailed description of the characteristics of these soils will be possible after a greater number of analyses are available. Thus far it can be stated, however, that the soils of the second and third type show frequently an acid reaction on litmus paper. Such soils are capable of decomposing chlorids to some extent, absorbing the base and liberating hydrochloric acid.

Now it is well known that certain plants, as barley and wheat, are very easily injured by acidity in the soil, while other plants, as potato and buckwheat, possess a certain power of resistance.^d A weak acidity of soils is sometimes beneficial, e. g. when tertiary phosphates, as rock phosphate and bone dust, serve as manure. These are then more readily dissolved for the absorption by the roots. But in the majority of cases a neutral soil will be preferable,

^a These red soils, mostly poor in humus, occur widely spread in Porto Rico and are in most cases fertile. Since they further contain only very small amounts of free aluminium hydroxyd to judge from results obtained by treatment with cold potassa solution of 5 per cent and by cold hydrochloric acid of 1 per cent, these soils cannot be classed with the genuine laterites often found in the tropics but with the group of soils called *tierra roja*.

^b The formation of this class of soils requires further study. As a rule, the laterite results from too much leaching by warm rains and shows an accumulation of ferric hydrate, aluminium hydrate, and silicates of both.

^c Acid soils were found by Daikuvara to owe their acidity sometimes to certain zeolitic silicates.

^d Maxwell mixed soils with 0.02 to 0.1 per cent citric acid and observed that cruciferous plants and clover rapidly perished in these mixtures. Wheat and barley, pea, vetch and lupin failed, maize developed flowers but no seed, only millet did well.

upon which phosphatic manure in the form of superphosphate will produce the best results. This is especially true for plants which develop at a rapid rate, as does tobacco, and demand, therefore, a most uniform distribution of the mineral nutrients within easy reach of the roots. Superphosphate, on account of its solubility, is capable of spreading through the soil, while ground rock phosphate is not. The 'hygienic' conditions for the roots of tobacco must be as perfect as possible, stiff clay must be loosened, acid soils must be neutralized by carbonate of lime, alkaline soils must be neutralized by gypsum (in some rarer cases magnesium sulphate may also come into consideration), and in cases of a considerable excess of the magnesia content over the lime content in a soil, liming with addition of gypsum will become necessary.

Of 16 samples of soils from tobacco plantations, 9 were found by the chemist to be "acid," 5 "strongly acid," 1 "slightly acid," and only 2 samples were found of neutral reaction. The fact that the acid soils prevail in those districts may be chiefly due to the warm summer rains which easily leach out the carbonate of lime. On the other hand, lands of alkaline reaction are found in some districts where warm summer rains are reduced to a minimum.

Soils of an alkaline reaction are found in the southern part of the island which are not reached by the northern air currents. These currents deposit their moisture chiefly on the main mountain range of the central elevations, reaching an altitude of 4,000 feet, and thus the lowlands south of this range receive only a meager supply of rain. There exist, however, a number of creeks that furnish water for irrigation. But this water does not suffice for an occasional flooding of the plantation grounds as is practiced on the paddy lands for rice culture but only for moistening the soil so far as the development of cane would require. Under such a condition the carbonates of potash and soda, resulting from the disintegration of the rocky particles of the soil, accumulate and cause an alkaline reaction. This reaction is, however, unfavorable for several reasons. In the first place it is itself injurious and unnatural to the roots; in the second place, the roots are thereby prevented from dissolving lime, magnesia, and phosphoric acid at the required rate for growth; and in the third place, those alkalis render the clay soil of these lowlands very stiff and thus obstruct aeration and root growth indirectly. The writer has seen perfectly barren spots, devoid of a single blade of grass, convincing evidence of the alkaline reaction of that soil.

The chemist of the station has examined 6 samples of soils from the cane plantations of these localities and observed with 2 of them "alkaline reaction," with 3 a "strongly alkaline" reaction, and with 1 a "slightly alkaline" reaction.

The fact that this alkaline reaction had not been recognized before explains the reason why former expensive manuring experiments did not fulfill expectations. Indeed phosphatic and potassic manures are here not required, only nitrogenous ones. If superphosphate showed some beneficial effect it was probably due more to having neutralized to some extent the alkaline reaction than to the supply of phosphoric acid. Some of these

lands suffer from still another fault, they show an excess of magnesia over lime. The figures of 3 samples may be mentioned:

RELATION OF LIME TO MAGNESIA IN SOME PORTO RICAN SOILS.

	CaO	MgO
	Per cent.	Per cent.
Sample from Limon.....	2.89	4.27
Sample from María Antonia, No. 1	2.40	8.90
Sample from María Antonia, No. 2.....	5.20	9.98

In these cases a heavy application of gypsum will be of triple benefit, it will do away with the alkaline reaction, it will render the soil more open and will antagonize to a certain extent the evil influence of the excess of magnesia over lime.^a This last mentioned condition was also observed with 14 of the 16 samples of tobacco land, and in half of these samples the magnesia content surpassed the lime content twofold and more. If this condition is found in soils of acid reaction, not gypsum alone, but slaked lime with addition of a certain amount of gypsum, should be applied, in order to correct the two defects as far as possible.

It will for these purposes be necessary to select a limestone free of magnesia or nearly free of it. Limestone samples from different parts of Porto Rico have shown a very low magnesia content, according to the chemist's analyses; one sample, however, from Quebradiillas with 34 per cent of lime contained also 18.17 per cent of magnesia. Such a dolomitic limestone may be applied on soils which at the same time are poor in lime and in magnesia. Whether soils occur in Porto Rico which would show, besides a high lime content, so small a content of magnesia that magnesia alone should be supplied as a manure is thus far not known. In such cases a moderate manuring with magnesium sulphate would be in order.^b In two of the samples of tobacco soils mentioned the lime content ran as low as 0.03 and 0.05 per cent, while the magnesia content amounted to 0.18 and 0.19 per cent, respectively. Liming will here prove of great benefit. There exist soils in Porto Rico which are much more benefited by liming than by the usual manuring, nitrogenous manure included, as an experiment with cane near this station has demonstrated. This soil suffers from three defects, viz., acidity, stiffness, and an excess of magnesia over lime. By the application of lime at the rate of 3,000 pounds per acre the yield of cane was increased 57 per cent. The yield that on the check plat was equal to 43.96 tons per acre was changed to the rate of 69.25 tons per acre by liming alone.

^a The most favorable ratio of lime to magnesia in the soil for cane will very probably be as 2 : 1, if both are present in an equal state of availability. This can be inferred from experiments with maize by Bernardini.

^b Crude sulphate of magnesia can be obtained at very low rates in Germany.

An experiment may here be mentioned which the writer proposed while in Tokyo, showing the powerful influence of lime on a soil that suffered from no other defect than an excess of magnesia (1.91 per cent) over lime (0.64 per cent). By adding 240 grams calcium carbonate to 10 kilograms of this soil, the yield of barley was just doubled.^a Full mineral manure had also been applied.

In reviewing the observations thus far made at this experiment station on the soils of cane and tobacco plantations in Porto Rico it becomes evident:

- (1) That these soils often show a very favorable percentage of potash and phosphoric acid.
- (2) That doubtless various defects exist in these soils,^b but they are of such a nature that they are easily remedied. Thus the outlook for increase of returns is a very favorable one.

^a Daikuhara, Bul. Imp. Cent. Agr. Exp. Sta. Japan 1, (1905), No. 1, pp. 13-16.

^b On certain "sick" soils a special report will follow later on

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